National Urban Air Quality Trends 1974-1981

Report EPS 7/AP/14
December 1984

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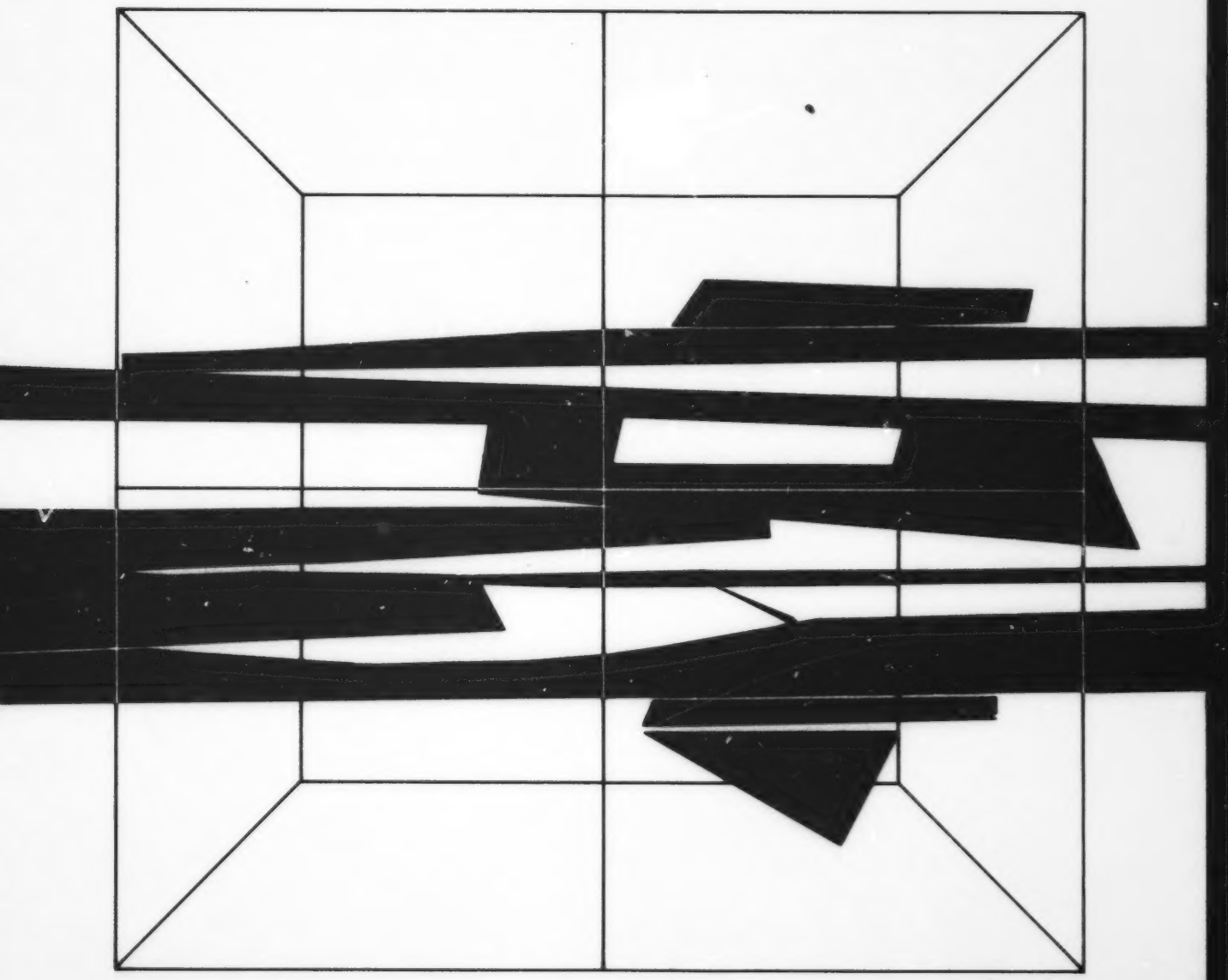

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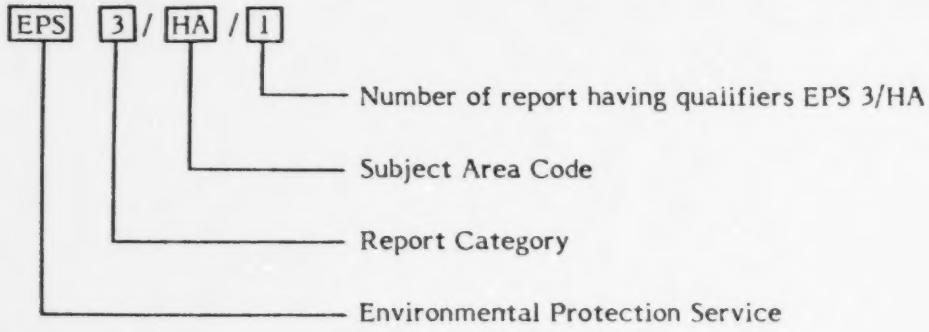

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NATIONAL URBAN AIR QUALITY TRENDS 1974-1981

Tom Furmanczyk
Inventory Management Division
Program Management Branch
Environmental Protection Service
Environment Canada

EPS 7/AP/14
December 1984

Comments

Comments regarding the content of this report should be addressed to:

Chief, Inventory Management Division
Program Management Branch
Environmental Protection Service
Environment Canada
Ottawa, Ontario
K1A 0C8

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Cat. No. En 49-5/7-14E
ISBN 0-662-13642-X
BEAUREGARD PRESS LIMITED

PREFACE

The air quality data analysed in this report were provided by the National Air Pollution Surveillance (NAPS) monitoring network, which maintains air monitoring stations in most Canadian cities with populations of over 50 000. The pollutants considered and the periods for which valid national data are available are as follows:

Sulphur dioxide, 1972 - present
Nitrogen dioxide, 1977 - present
Carbon monoxide, 1973 - present
Ozone, 1979 - present
Suspended particulates, 1970 - present
Lead, 1970 - present
Soiling index, 1970 - present

Monitoring data have been analyzed to determine trends in national average annual concentrations of these contaminants, and have also been compared with the National Ambient Air Quality Objectives. The NAAQO's define three levels of contaminant concentration:

1) Maximum Desirable - defines the long-term goal for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology.

2) Maximum Acceptable - is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being.

3) Maximum Tolerable - denotes a concentration of an air contaminant that requires abatement without delay to avoid further deterioration to an air quality that endangers the prevailing Canadian lifestyle or, ultimately, to an air quality that poses a substantial risk to public health.

These levels are defined for various contaminants at various concentrations for different periods of time.

The NAPS data represent pollution levels at individual sampling sites and may not necessarily represent community-wide air quality. Community-wide comparisons can only be made using data from all available sampling stations within a city, and interpreting these data on the basis of specific sampling and site characteristics.

Mean concentrations have been derived as arithmetic means for all contaminants except suspended particulate matter and particulate lead, where geometric means have been used.

The data used for analysis in this report spans the period 1974 to 1981. This was done in an effort to compare data that are representative of annual conditions, since completeness criteria were first applied to the NAPS data in 1974.

PRÉFACE

Les données sur la qualité de l'air qui sont analysées dans le présent rapport proviennent du Réseau national de surveillance de la pollution atmosphérique (Réseau NSPA) qui a des stations dans la plupart des villes canadiennes de plus de 50 000 habitants. Voici quels sont les polluants mesurés et les périodes pour lesquelles des données nationales valides sont disponibles:

Anhydride sulfureux, à partir de 1972;
Dioxyde d'azote, à partir de 1977;
Monoxyde de carbone, à partir de 1973;
Ozone, à partir de 1979;
Particules en suspension, à partir de 1970;
Plomb, à partir de 1970;
Indice de souillure, à partir de 1970.

Les données ont été analysées afin de déterminer les tendances des concentrations annuelles moyennes nationales de ces contaminants et ont été comparées avec les Objectifs établis de qualité de l'air ambiant. Trois niveaux de concentration des contaminants peuvent être fixés dans les Objectifs afférents à la qualité de l'air ambiant:

1) Le niveau maximal souhaitable correspond à l'objectif de qualité de l'air à long terme et sert de guide dans l'application du principe de non-dégradation des parties non polluées du pays et pour le perfectionnement continu des techniques antipollution.

2) Le niveau maximal acceptable doit assurer une protection adéquate contre les effets dommageables aux niveaux du sol, de l'eau, de la végétation, des matériaux, des animaux, de la visibilité et du bien-être.

3) Le niveau maximal tolérable correspond à une concentration qui doit être réduite sans retard afin d'empêcher une détérioration plus grave de la qualité de l'air qui, à la longue, menacerait le style de vie actuel des Canadiens et ferait peser un risque important sur la santé de la population.

Ces niveaux sont établis pour divers contaminants à diverses concentrations pour différentes périodes de temps.

Les données fournies par le Réseau NSPA correspondent aux niveaux de pollution enregistrés aux stations d'échantillonnage et ne sont pas nécessairement représentatives de la qualité générale de l'air dans une agglomération. Pour faire des comparaisons entre agglomérations, on doit uliliser les données obtenues de toutes les stations d'échantillonnage des agglomérations considérées et interpréter ces données en fonction des caractéristiques particulières des procédés et emplacements d'échantillonnage.

Les concentrations moyennes ont été établies à partir des moyennes arithmétiques pour tous les contaminants sauf pour les particules en suspension et le plomb particulaire dans quels cas les moyennes géométriques ont été employées.

Les données analysées couvrent la période de 1974 à 1981. Le début de la période a été fixé à 1974, car c'est la première année où des critères d'intégralité ont été appliqués aux données du Réseau et qu'on voulait comparer des données qui étaient représentatives des conditions annuelles.

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SUMMARY

Average annual concentrations of most contaminants monitored in the National Air Pollution Surveillance (NAPS) network decreased substantially between 1974 and 1981. Decreases were smaller in recent years, resulting in relatively constant levels between 1977 and 1981. Exceptions are suspended particulates and lead, which have decreased by 12% and 18%, respectively, since 1979.

The average annual sulphur dioxide concentration decreased by approximately 30% between 1974 and 1981. In recent years, approximately 95% of the sulphur dioxide data from NAPS monitoring stations have met the maximum acceptable annual level defined in the National Ambient Air Quality Objectives, compared with approximately 80% in 1974. Data from approximately 25% of the stations show that sulphur dioxide exceeded the maximum desirable annual level in 1981. For 24-hour periods, the percentage of stations reporting readings greater than the maximum desirable level increased from 40% in 1974 to 50% in 1981. However, the percentage of stations reporting readings exceeding the maximum acceptable 24-hour level decreased by about 10% during this period. The maximum tolerable level was exceeded only four times during the 1974-81 period. For 1-hour periods, approximately 45% of the stations reported readings that exceeded the maximum desirable level while approximately 15% reported readings that exceeded the maximum acceptable level. No significant short-term changes have occurred.

Reliable nitrogen dioxide data are available only for 1977-81 during which time the average annual concentration decreased approximately 15%. The number of stations with average annual concentrations higher than the maximum desirable level decreased from approximately 40% in 1977 to 15% in 1981. No stations provided annual averages that exceeded the maximum acceptable level from 1978 to 1981. In 1981, 8% of the stations reported readings that exceeded the maximum acceptable 24-hour level, compared with 16% in 1977. One station reported readings that exceeded the maximum tolerable 24-hour level. Only 14% of the stations reported readings that exceeded the maximum acceptable 1-hour level in 1981, representing an increase over the previous two years.

The annual average concentration for carbon monoxide decreased approximately 30% between 1974 and 1976, but remained relatively constant thereafter. The small but persistent decline in the percentages of stations reporting readings exceeding the 8-hour objectives in earlier years was offset by small increases in 1979. Approx-

imately 85%, 12% and 2% of the stations reported readings that exceeded the maximum desirable, acceptable and tolerable 8-hour levels, respectively, in 1981. The percentage of stations reporting readings exceeding the maximum desirable 1-hour level was lower (50%) in 1980 and 1981 than in earlier years (70%).

Ozone measurements are reported for 1979 to 1981 and the average of the annual mean concentrations are in the range of 15 parts per billion (ppb). Fifty percent of the stations provided annual mean concentrations that exceed the maximum acceptable ambient air quality objective. Almost all stations reported 24-hour average values in excess of the maximum acceptable level. Approximately 90% and 10% of the stations reported 1-hour values in excess of the maximum acceptable and tolerable levels, respectively, for 1980 and 1981.

The average of the annual geometric means for suspended particulates decreased by approximately 25% between 1974 and 1981, and since 1975 has stabilized in the 50 and 60 micrograms per cubic metre ($\mu g/m^3$) range. In 1981, approximately 20% of the stations provided mean concentrations that exceeded the maximum acceptable annual level, compared with 50% in 1974. Similarly, the percentage of stations with mean values exceeding the maximum desirable level decreased from 70% in 1974 to 40% in 1981. The percentage of stations reporting readings meeting the 24-hour objective did not change significantly between 1974 and 1981; approximately 85% and 8% reported values that exceeded the maximum acceptable and tolerable levels, respectively.

The average of the annual geometric means for lead concentrations decreased approximately 50% from 1974 to 1981. The national average concentration maxima decreased from 3.0 $\mu g/m^3$ in 1974 to 1.1 $\mu g/m^3$ in 1981, indicating a continuing improvement in ambient concentrations of this contaminant.

Although the average of the annual means for the soiling index decreased approximately 20% from 1974 to 1981, average levels were relatively constant between 1975 and 1979.

The averages of annual mean contaminant levels calculated for all stations and for Class I* stations have been compared. With the exception of lead, and to a lesser extent the soiling index, good agreement is shown for the 1979-1981 period. Class I stations thus provide a representative national sample of contaminant levels and trends. Further reductions in ambient lead levels can be expected with the continuing decline in the use of leaded gasoline.

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*Class I stations are located in areas of high population density.

Annual air quality indexes for all Class I stations in operation between 1977 and 1981 have been calculated. The majority of sites may be categorized as "Fair", three as "Good" (Hull, Victoria, and one station site in Vancouver), and three as "Poor" (Regina, and one station site each in Winnipeg and Montreal). The three station sites with poor index values are in commercial areas affected by heavy vehicular traffic.

1 INTRODUCTION

1.1 Purpose and Scope

This is the fourth in a series of reports (1,2,3) on ambient air quality trends in Canada issued by the Environmental Protection Service. Its purpose is to summarize and interpret the ambient air quality data collected through the National Air Pollution Surveillance (NAPS) Network (4) and to report significant changes indicated by statistical and other forms of analysis. The monitoring results discussed cover the 1974-81 period.

The NAPS program was initiated in January 1970 to provide a nationwide data base for determining air quality in the major urban centres in Canada and to document the effects of changing industrial activity, fuel use patterns and population density, more extensive use of pollution control equipment, and other factors. Air monitoring stations are maintained in most Canadian cities with populations over 50 000. Monitoring instruments are usually located at sites where air pollution could present a problem and where a large number of people could be affected.

The site of air monitoring instruments is referred to as a "monitoring station", and each station is classified according to the following zoning classifications:

C - Commercial
R - Residential
I - Industrial

Recently, guidelines have been established categorizing NAPS stations as Class I, Class II, or Special (5). The Class I network is the permanent national network of comprehensive monitoring sites which will be operated over the coming decades. These sites were selected to represent areas of highest population exposed to prevailing air quality. The Class II stations may be operated on a shorter-term basis when and where there is a demonstrated need for monitoring. They are pollutant-oriented but not necessarily source-oriented. Special stations are established to monitor regional air quality, long-range transport or other specific pollution problems of national significance.

Any comparison of data between stations must take these designations into account. Even when comparing contaminant levels in different cities for a specific type or class of station, caution should be exercised. The data represent the condition of the air in the vicinity of the individual monitoring stations but may not necessarily represent community-wide air quality.

The contaminants monitored are sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), suspended particulates (SP), and lead. In addition, the soiling or darkening potential of contaminants in the atmosphere is measured as the soiling index or coefficient of haze (COH), and measurements are made of dustfall and sulphation rates.

The great volume of air monitoring data generated by the nationwide network indicated the need for a single-value air quality index that could be used for socio-economic modelling, as an indicator of air quality trends, and as a basis for making rough comparisons of air quality in different urban areas. "Guidelines for an Annual Air Quality Index" were published by the Environmental Protection Service, on behalf of the Federal-Provincial Committee on Air Pollution in 1980 (6). The index is based on the National Ambient Air Quality Objectives (7) and assumes that, at the defined objective levels, these individual air pollutants are equally important air quality indicators. The objectives reflect the entire range of pollutant effects, not just effects on health.

Since 1974, the NAPS annual summaries have not reported annual means of a contaminant for stations that do not meet a set of completeness criteria because this could result in values of questionable accuracy. For SO_2, NO_2, O_3, CO and COH, monthly or annual means are not calculated unless at least 50% of the hourly observations are available for the period concerned. Furthermore, the annual mean is not calculated unless monthly means are reported for at least two months in each quarter. For SP and lead, a monthly mean is not reported in the NAPS annual summaries unless a minimum of three samples is available for that month. The conditions for reporting the annual geometric mean are a minimum of 40 samples in the year with at least 8 valid samples for each quarter.

1.2 Air Monitoring Program

When established in January 1970, the NAPS network had 43 monitoring instruments in 14 cities, measuring SO_2, SP, lead and COH. By December 1981 the number of instruments had increased to 448 in 54 cities across the ten provinces and two territories and the list of contaminants monitored had expanded to include CO, NO_2 and O_3*. The growth of the network is illustrated in Figure 1 while Figure 2 shows the cities where monitoring instruments are located. Table 1 lists the Class I stations, their

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* Another 52 instruments were used to measure dustfall and sulphation rate, but these two indicators of air pollution are not dealt with in this report.

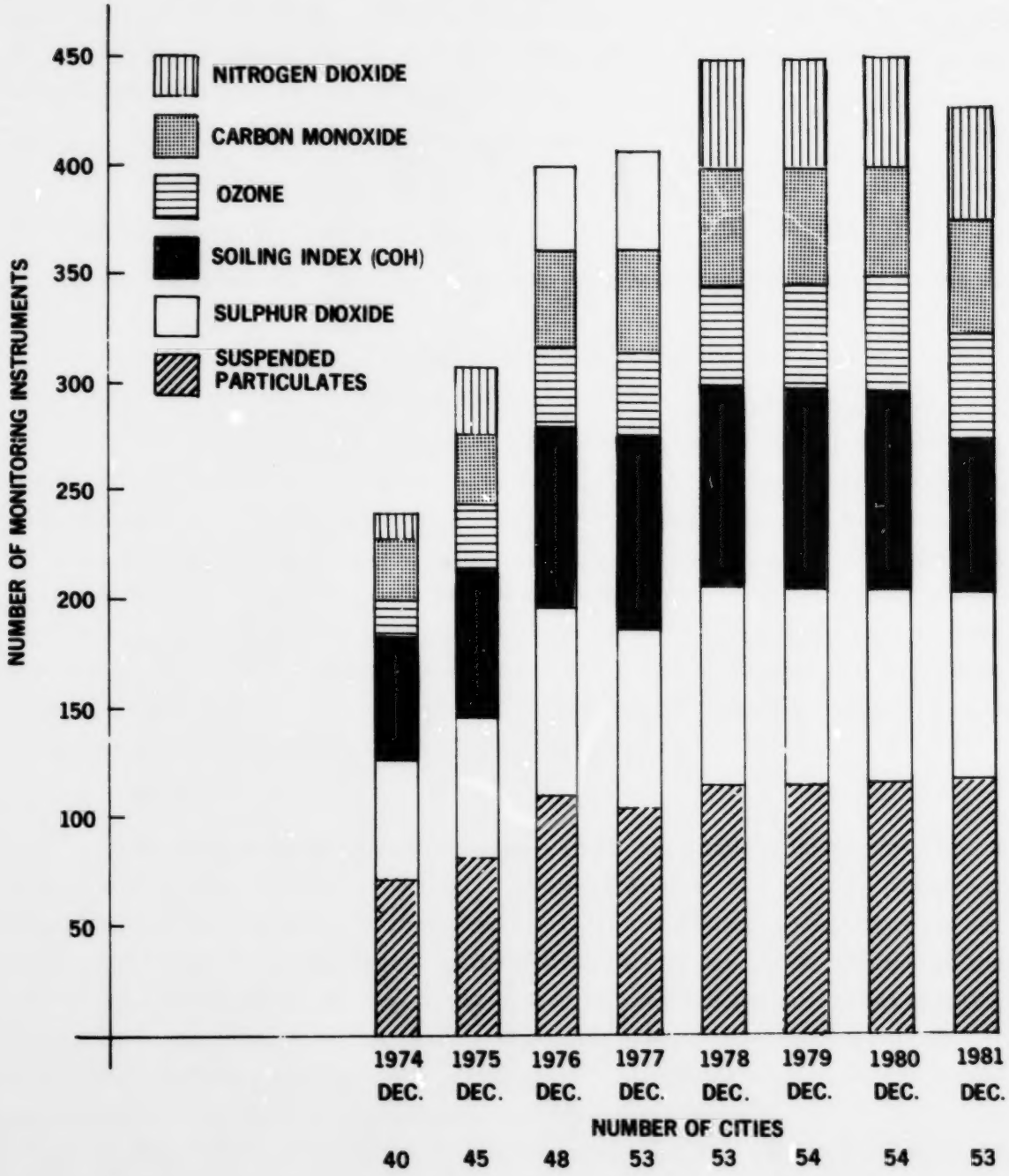

FIGURE 1 DISTRIBUTION OF STATIONS IN NAPS NETWORK 1974-1981

FIGURE 2 NATIONAL AIR POLLITION SURVEILLANCE NETWORK (MARCH 1981)

location and current status. When installation is completed, all air quality objective parameters and the coefficient of haze will be monitored at the Class I stations. Most of the stations are located in downtown or major residential areas with potential for poor air quality, consistent with the site selection criteria (5).

1.3 National Ambient Air Quality Objectives

Air quality objectives have been established as a guide in developing programs to reduce the damaging effects of air pollution (7). These national objectives:

- assist in establishing priorities for reducing contaminant levels and the extent of pollution control needed;
- provide a uniform yardstick for assessing air quality in all parts of Canada;
- indicate the need for and extent of monitoring programs.

The maximum acceptable level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being. The maximum desirable level defines the long-term goal for air quality and provides a basis for an anti-degradation policy in unpolluted areas of the country. The maximum tolerable level denotes concentrations of air contaminants that require abatement without delay to avoid deterioration to an air quality that endangers the prevailing Canadian lifestyle or, ultimately, to an air quality that poses a substantial risk to public health. Table 2 presents the desirable, acceptable and tolerable levels for the contaminants and conditions of interest in the present analysis.

1.4 Analytical Methods

1.4.1 Wilcoxon Matched Pairs Signed-Ranks Test. The details of this procedure have been described in a previous report (1). A non-parametric test of high power and efficiency, it is an alternative to the paired t-test (8) and provides an assessment of the magnitude of the differences between paired observations as well as the direction of the differences. In this study, the test has been used to overcome the difficulties resulting from a continual increase in the number of stations measuring each contaminant. It determines whether there has been a statistically significant change in the annual averages of a contaminant at all monitoring stations across Canada.

The annual mean levels of a contaminant for two consecutive years are compared at each station. Data for two consecutive years are required and the size of the increase or decrease is noted. If a high proportion of stations experienced an increase, the test will show whether the increase was statistically significant for those

TABLE 1 NATIONAL AIR POLLUTION SURVEILLANCE CLASS I STATIONS
(Status as of December 31, 1980)

City	Station	Location	Comments
Newfoundland			
St. John's	10101C	Duckworth & Ordinance	Incomplete
Nova Scotia			
Halifax	30116C	Barrington & Duke	High-Volume sampler sited at 30101C
New Brunswick			
Saint John	40202C	Post Office	High-Volume sampler sited at 40201C
Quebec			
Montreal	50115C	Metcalf & Maisonneuve	
	50116R	3161 Joseph, Verdun	
	50102R	Jardin Botanique	No CO monitor
	50109C	Duncan & Decarie	
	50112C	Boul. Laurentides	No Soiling Index monitor
	50110C	Parc Pilon, Montreal-Nord	
Hull	50203R	Gamelin & Joffre	No O_3 monitor
Quebec City	50304C	325 Dorchester Sud	No Soiling Index monitor
	503XXX		Site not yet identified
Ontario			
Ottawa	60101C	88 Slater Street	
	60105R	National Research Council	No CO monitor
Windsor	60204C	471 University Avenue	
Toronto	60401C	67 College Street	
	60412R	Bathurst & Wilson	No O_3 monitor
	60410R	Lawrence & Kennedy	
	60415R	Queensway W. & Hurontario	
	60402R	Don Mills, Science Centre	
	60413R	Elmcrest Road	
Hamilton	60501C	Barton & Sanford	
	605XXX		Site not yet identified
London	60901C	King & Rectory	
St. Catharines	61301C	North & Geneva	

TABLE 1 NATIONAL AIR POLLUTION SURVEILLANCE CLASS I STATIONS (Status as of December 31, 1980) (continued)

City	Station	Location	Comments
Kitchener	61501C	Edna & Frederick	
Manitoba			
Winnipeg	70119C	65 Ellen Street	
	70118R	Jefferson & Scotia	
Saskatchewan			
Regina	80109C	1620 Albert Street	
Alberta			
Edmonton	90130C	10255-104th Street	
	90122R	127 Street & 133rd Avenue	
Calgary	90227C	1611-4th Street S.W.	High-Volume Sampler sited at 90204C
	90222R	39 Street & 29th Ave. N.W.	
British Columbia			
Vancouver	00112C	Robson & Hornby	High-Volume Sampler sited at 00109C
	00106R	2294 West 10th Avenue	
	00108I	250 West 70th Avenue	
	00110R	E. Hastings & Kensington	
	00111I	Rocky Pt. Park	
Victoria	00302C	1106 Cook Street	To be relocated

two years. A 95% confidence interval is used. The pictorial summary of trends for each contaminant from 1974 to 1981 is displayed in Table 3, and will be discussed further in the sections on individual contaminants.

The Wilcoxon test was also used to determine the equivalence of trends in air quality defined by Class I stations compared to all stations, using 1980-81 data. As shown in Table 4, the two groups of stations show similar trends for nitrogen dioxide, carbon monoxide, soiling index, suspended particulates and lead, but not for sulphur dioxide. Comparisons of the longer-term trends indicated by Class I stations and all stations are given in the sections on individual contaminants.

TABLE 2 NATIONAL AMBIENT AIR QUALITY OBJECTIVES*

Pollutant	Averaging Time	Maximum Desirable Concentration		Maximum Acceptable Concentration		Maximum Tolerable Concentration	
Sulphur dioxide	Annual	11	ppb**	23	ppb	-	
	24-h	60	ppb	110	ppb	310	ppb
	1-h	170	ppb	340	ppb	-	
Suspended Particulates	Annual	60	$\mu g/m^3$	70	$\mu g/m^3$	-	
	24-h		-	120	$\mu g/m^3$	400	$\mu g/m^3$
Ozone	Annual		-	15	ppb	-	
	24-h	15	ppb	25	ppb	-	
	1-h	50	ppb	80	ppb	150	ppb
Carbon Monoxide	8-h	5	ppm***	13	ppm	17	ppm
	1-h	13	ppm	31	ppm	-	
Nitrogen Dioxide	Annual	32	ppb	53	ppb	-	
	24-h		-	110	ppb	160	ppb
	1-h		-	210	ppb	530	ppb

* Conditions of 25°C and 101.32 kPa are used as the basis for conversion from $\mu g/m^3$ to ppm or ppb.
** Parts per billion
*** Parts per million

The Class I station data for 1980-81 were also used to compare the paired t-test and Wilcoxon Matched Pairs Test. The paired t-test is a parametric test, it uses the t distribution to determine the difference between matched pairs of data. A parametric test could be used in this case because the Class I network has become stable with respect to monitoring sites and instrumentation. The Wilcoxon test also uses the variability of the difference between two matched sets of data to determine if a statistically significant difference exists. Statistical significance is set at a 95% confidence limit. The trend analyses for the 1980-81 data for each contaminant by the two methods are summarized in Table 4. In all but one case the trends are in agreement, indicating a reasonable consistency between the two methods. For SO_2 the Wilcoxon test (all stations) indicates a decrease whereas the paired t and the Wilcoxon (Class I stations) indicate no trend. One important consideration concerning the SO_2 analysis was that for 1980-81 the number of paired data sets was greatly reduced.

TABLE 3 STATISTICALLY SIGNIFICANT CHANGES IN AIR POLLUTION LEVELS, BASED ON ANNUAL MEANS FOR NAPS STATIONS ACROSS CANADA DURING 1974-81

Contaminant	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81
Sulphur Dioxide	→	↓	→	→	↓	→	→	↓
Nitrogen Dioxide	N/A	N/A	N/A	N/A	→	↓	→	→
Carbon Monoxide	↓	↓	→	→	→	→	↓	→
Ozone	N/A	N/A	N/A	N/A	N/A	→	→	↓
Suspended Particulates	→	↓	→	↓	→	↑	↑	↓
Lead	↓	↓	↓	↓	↓	↓	↓	→
Soiling Index	→	→	→	→	→	→	↓	↑

↑ = Statistically Significant Increase

↓ = Statistically Significant Decrease

→ = Statistically No Significant Change

N/A = Not applicable; pollutant not monitored or results not considered reliable.

TABLE 4 COMPARISON OF TREND ANALYSES USING WILCOXON AND PAIRED t-TESTS (1980-81 DATA)

Pollutant	Wilcoxon Test All Stations	Wilcoxon Test Class I Stations	Paired T-Test Class I Stations
SO_2	Signif. decrease	No trend	No trend
CO	No trend	No trend	No trend
NO_2	No trend	No trend	No trend
Soiling Index	Signif. increase	Signif. increase	Signif. increase
Suspended Particulates	Signif. decrease	Signif. decrease	Signif. decrease
Lead	No trend	No trend	No trend

These statistical methods take into account changes in air contaminant levels that may be due to monitoring instrument sensitivity and other errors when determining whether the change is significant. A disadvantage of these tests when applied to data for consecutive years is that slight increases or decreases in each year, not considered statistically significant in consecutive years, might lead to substantial increases or decreases over the longer term. Other methods must be used to assess the significance of longer-term trends, and to this end longer-term trend plots are included in this report.

1.4.2 Box Plot Analysis. The box plot is a graphical technique used in exploratory data analysis to show the distribution of the annual means calculated for the various contaminants. The plotting convention for the box plot is shown in Figure 3. For a given contaminant, the annual averages (or geometric means in the case of SP and lead) for all stations are grouped and ranked*. The percentiles indicate the percentage of stations with annual averages less than (favorable) or greater than (unfavorable) the specific levels identified.

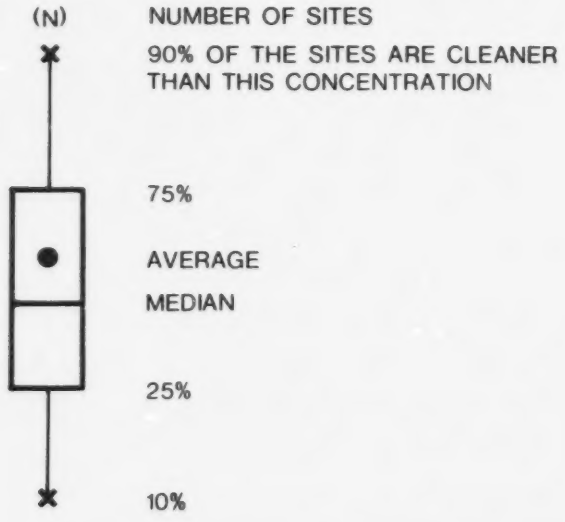

FIGURE 3 CONCENTRATION BOX PLOTTING LEVELS

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* The change in the number of stations from year to year could possibly bias the annual average or percentiles calculated, distorting actual trends. To account for this, averages and percentiles were calculated for data from all stations and Class I stations. Values and corresponding trends for both were found to be similar. Consequently, because the total NAPS network gives a more representative national sample, data from all stations have continued to be used in the analysis.

In addition to the percentiles (10, 25, 50, 75 and 90), the annual average of all stations for the particular contaminant in a given year is also displayed. Thus, the annual trends at the favorable (10-25 percentiles), average (mean, median (50)), and unfavorable (75 and 90 percentiles) stations can be analyzed separately (see Appendix, Summary Data - Urban Air Quality Trends, 1970-81).

1.4.3 **Analysis with Respect to NAAQOs.** A third type of analysis used is based on the percentages of station data meeting or exceeding the NAAQOs in given years. This type of analysis is crude because it is insensitive to movement within particular ranges. For example, all stations recording an annual mean for a particular contaminant may experience a decrease in the mean concentration from one year to the next. However, if none of the annual means drops below a particular objective, then this type of analysis would indicate no change. Caution should be exercised when considering concentration levels higher than short-term air quality objectives (1 h, 8 h, 24 h). A single occurrence will register a station as exceeding a particular level, be it desirable, acceptable or tolerable, even though this may be one in several thousand readings taken at that station. In the table below the one-hour desirable level for carbon monoxide (13 ppm) has been exceeded at five Toronto stations; the acceptable level (31 ppm) has been exceeded at one of these stations.

Station	Location	1-hour Average CO, 1981		Total Readings
		> Desirable	>Acceptable	
60401C	67 College Street	14	0	3476
60402R	Don Mills, Science Cntr	0	0	8105
60403I	Evans and Arnold	0	0	8387
60410R	Lawrence and Kennedy	1	0	8450
60412R	Bathurst and Wilson	1	0	8516
60413R	Elmcrest Road	0	0	7149
60414I	Sherbourne and Wilton St.	0	0	8299
60415R	Queensway W and Hurontario	8	0	8607
60416C	381 Yonge Street	293	17	8481
60417C	26 Breadalbane	0	0	4297

If a comparison is made between station 60416C and 60401C, approximately 4.0% of the readings at station 60416C exceed the desirable level, whereas 0.4% of the readings at the other station exceed the same level. This type of analysis tends to identify potential air quality problems at specific sites. Consequently, it is used more in a supportive role to substantiate the first two types of analysis. For the same reason as in the box plot analysis, all stations have been used in calculating the percentage of stations with readings meeting or exceeding NAAQOs.

2 SULPHUR DIOXIDE

Sulphur dioxide (SO_2) is a colourless gas and normally is not present in urban air at concentrations high enough for its odour to be detected. It is emitted into the atmosphere mainly from the primary production of copper and nickel, the combustion of sulphur-containing fuels, natural gas processing, iron ore processing and petroleum refining. Although air quality objectives for this contaminant have been set on the basis of known primary effects on health, vegetation and materials, secondary effects resulting from sulphur dioxide's role in the formation of acid rain are now also of concern.

2.1 Annual Means

The average of sulphur dioxide annual means recorded by the NAPS network has decreased from 16 ppb in 1974 to 11 ppb in 1981 (see Figure 4 and Appendix). Small changes in annual mean values have occurred in recent years. Statistical methods have been used to determine whether the changes in any two consecutive years are significant, and it has been determined that significant decreases occurred in 1974-75, and 1977-78 (see Table 3). Table 5 shows the number of stations whose data show statistically significant changes in annual arithmetic means. A trend in recent years to a larger number of stations showing no change is apparent.

Trends in annual mean values for all stations and for Class I stations are shown graphically in Figure 5. The Class I stations provide a sample of sulphur dioxide levels and trends typical of urban centres across Canada.

Despite the rather small changes in annual mean values, significant improvement in sulphur dioxide levels has occurred. In recent years, more than 90% of the monitoring stations have reported values less than the maximum acceptable objective. For the past seven years, levels at more than 50% of the sites have met the maximum desirable objective. Table 6A summarizes the percentages of stations with readings in various ranges with respect to the annual NAAQOs for 1974-81. Figure 6A shows the percentages of stations exceeding the objectives. The improvement achieved during this period is apparent in both instances.

Overall mean values from all stations in Canada that meet NAPS siting criteria compare favorably with the objectives, although some stations have continued to register values in excess of the maximum acceptable level of 23 ppb (Table 7). The highest levels over the last two years have been recorded in Montreal and Baie Comeau. Point sources (industrial establishments) associated with those stations are oil refineries,

TABLE 5 SULPHUR DIOXIDE - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1974-81)

Period	Number of Stations			
	Decrease	Increase	No change **	Total
1972-73*	23	2	7	32
1973-74	6	6	12	24
1974-75*	11	2	10	23
1975-76	7	4	18	29
1976-77	11	9	20	40
1977-78*	19	4	30	53
1978-79	12	6	40	58
1979-80	12	9	35	56
1980-81*	7	2	31	41

* Statistically, there was a significant decrease in sulphur dioxide levels for the years 1974-75, and 1977-78, and 1980-81.

** Includes differences of less than 1.0 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors.

pulp and paper mills and an aluminum smelter. The continuing use of oil as a major residential heating fuel as well as for commercial and institutional purposes in Quebec also contributes significantly to sulphur dioxide levels in these urban areas.

2.2 Short-Term Concentrations

24-hour Maximum Levels. The percentages of stations with readings in the 24-hour maximum NAAQO range indicate a change in the frequency distribution of 24-hour average sulphur dioxide concentrations between 1974 and 1981 (Table 6 and Figure 6). In this period, the percentage of stations having readings greater than the maximum desirable level increased from 40% to 50%. However, the number of stations having readings greater than the maximum tolerable 24-hour level did not change significantly. Thus a small change in the frequency distribution of 24-hour average values appears to have occurred in favour of a larger number of values in the 61-110 ppb range. The number of valid annual means increased from 55 in 1974 to 82 in 1981; this would strongly influence the frequency distribution.

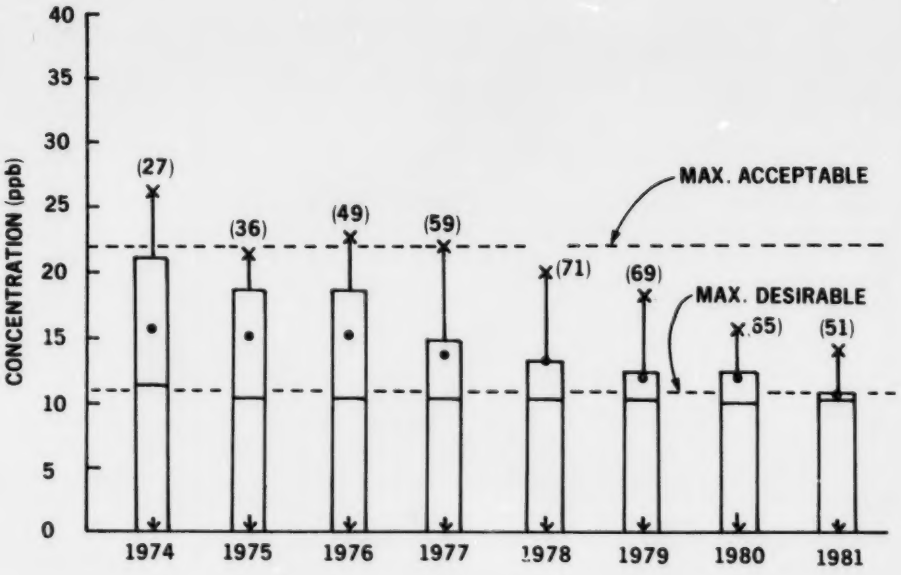

FIGURE 4 SULPHUR DIOXIDE ANNUAL CONCENTRATION TRENDS IN CANADA (1974-1981)

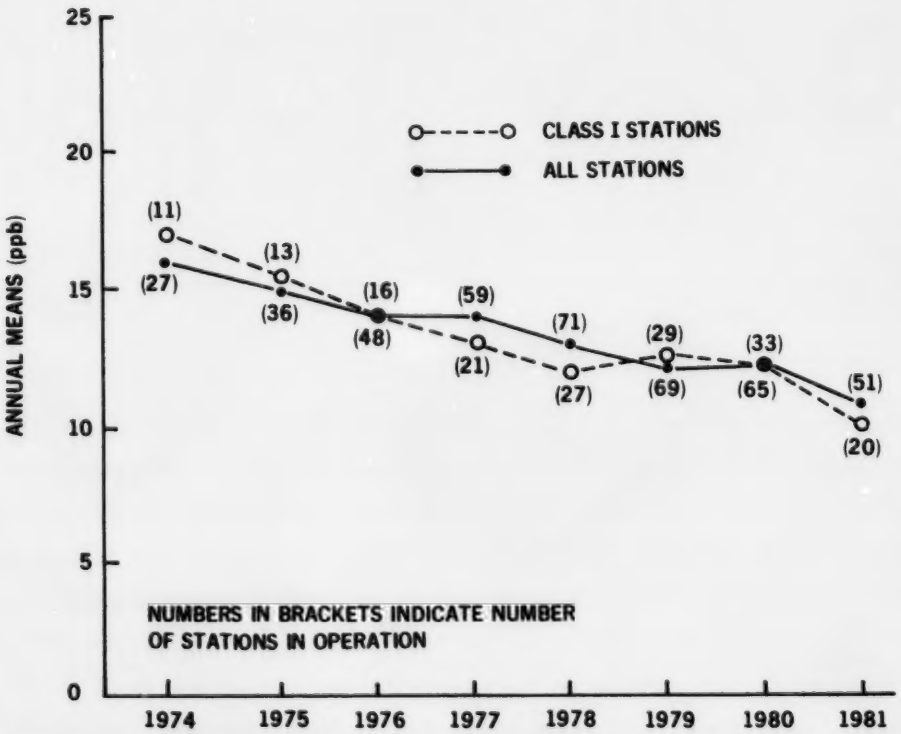

FIGURE 5 TRENDS IN SO_2 ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1974-1981)

TABLE 6 SULPHUR DIOXIDE - PERCENTAGE OF STATIONS WITH READINGS IN VARIOUS RANGES WITH RESPECT TO THE NATIONAL AMBIENT AIR QUALITY OBJECTIVES (1974-81)

Range (ppb)	1974	1975	1976	1977	1978	1979	1980	1981
A) Annual Means								
0 - 11*	41	53	54	59	68	67	65	75
12 - 23**	41	36	36	36	25	29	34	23
>23	18	11	10	5	7	4	1	2
No. of stations	27	36	48	59	71	69	65	51
B) 24-hour Maximum								
0 - 60*	60	59	56	54	42	41	57	49
61 - 110**	25	24	29	24	44	44	36	38
111 - 310***	15	17	15	21	13	15	6	12
>310	--	--	--	1	1	--	1	1
No. of stations	55	63	75	83	92	90	89	82
C) 1-hour Maximum								
0 - 170*	56	57	56	59	61	62	74	55
171 - 340**	31	21	33	23	22	27	16	30
>340	13	22	11	18	17	11	11	15
No. of stations	55	63	75	83	92	89	88	82

* Desirable level
** Acceptable level
*** Tolerable level

The maximum tolerable level was exceeded at only two sites during 1974-1981: at the Quebec City industrial station of Centre Loisirs Limoilou, and at the residential station in Baie Comeau. In 1981 one reading from the Baie Comeau station exceeded the 24-h maximum tolerable limit (310 ppb), while there were insufficient valid data from the Centre Loisirs Limoilou station to determine an annual mean. Both stations are located near industrial as well as residential, commercial and institutional heating sources. The single-day exceedance could be influenced by meteorological factors such as a temperature inversion, wind speed and direction, etc. Most stations registered concentrations within the 24-h acceptable range, i.e., 93% in 1980 and 87% in 1981.

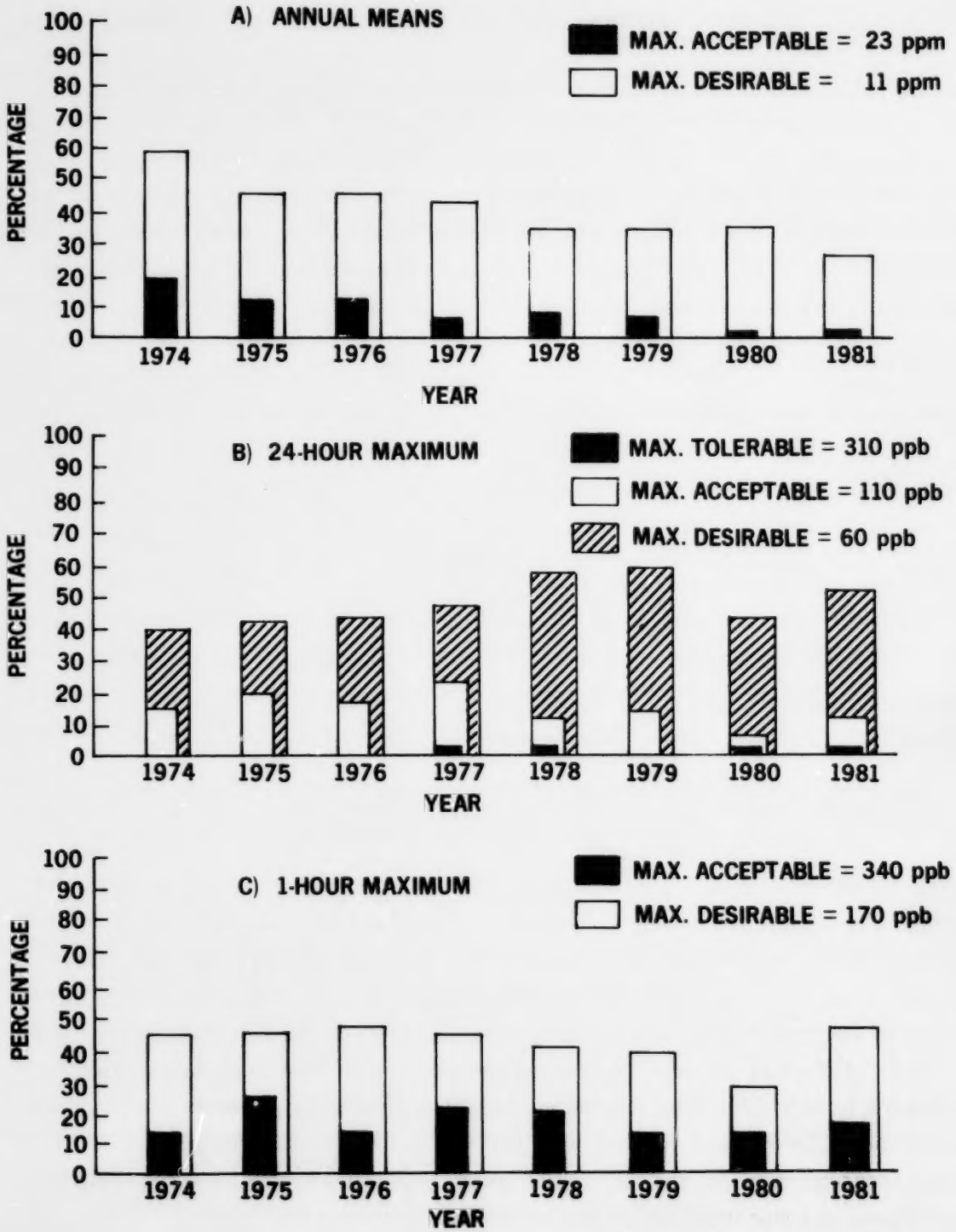

FIGURE 6 SULPHUR DIOXIDE - PERCENTAGE OF STATIONS REPORTING READINGS EXCEEDING NAAQOs (1974-1981)

TABLE 7 SULPHUR DIOXIDE - HIGHEST ANNUAL MEANS BY STATION LOCATION (1974-81)

City (Station)	Annual means (ppb)							
	1974	1975	1976	1977	1978	1979	1980	1981
Quebec City (503031)	NM	NM	30	43	20	25	19	NM
Quebec City (50304C)	NM	NM	24	26	15	18	14	14
Baie Comeau (51301R)	NM	NM	NM	NM	36	20	20	21
Shawinigan (512011)	NM	NM	NM	NM	26	---	15	17
Trois-Rivieres (50801R)	NM	NM	22	23	22	16	12	14
Montreal (50104C)	26	25	24	19	18	17	16	16
Montreal (50105C)	NM	37	27	36	28	25	20	16
Montreal (50115C)	NM	NM	NM	NM	27	27	35	---
Montreal (50103R)	30	22	22	21	28	19	---	23
Sudbury (60606C)	NM	NM	NM	23	13	11	13	10
Sudbury (60602R)	33	28	19	15	12	12	16	10
Windsor (60204C)	33	29	27	22	18	13	11	12
Windsor (60211R)	NM	23	20	15	15	18	10	10

--- Insufficient data for calculation of a valid mean.
NM Not measured.

1-hour Maximum Levels. When the 1-hour levels were analyzed with respect to the NAAQOs, no significant change was apparent from 1974 to 1981, apart from a small decrease in the percentage of stations having readings greater than the maximum desirable level in 1978 and 1979 (Figure 6 and Table 6). In 1974, 87% of the NAPS stations registered values that met the maximum acceptable level of 340 ppb, compared with 85% in 1981. Individual stations registering levels greater than the 1-hour maximum acceptable level in 1981 were located in Glace Bay, Quebec City, Rouyn, Trois-Rivières, Baie Comeau, Toronto and Sudbury, with the Baie Comeau station recording the highest 1-hour concentration in the last three years. Industrial point sources contribute significantly to ambient sulphur dioxide levels at all of these sites.

3 NITROGEN DIOXIDE

Gasoline-powered motor vehicles are the predominant source of nitrogen dioxide emissions. Other significant sources include diesel engines, industrial fuel combustion, power plants, forest fires and railway engines. Although the NAAQOs for this contaminant were established to prevent adverse human health effects and plant damage, the major role of nitrogen oxides in atmospheric photochemical reactions is also recognized, as is their significant contribution to acid rain.

As shown in Figure 1, nitrogen dioxide monitors were installed in the NAPS network in 1973. Data for the 1974-77 period were discussed in a previous report (2). It has since been concluded that the data obtained prior to 1977 are unreliable due to instrumental and calibration difficulties. Nitrogen dioxide data for the 1977-81 period only are considered in this report.

3.1 Annual Means

From 1977 to 1981, the average of nitrogen dioxide annual means decreased from 31 ppb to 23 ppb (see Appendix and Figure 7). Statistical tests indicate that no significant change in the national annual mean value occurred for the 1980-81 period (Table 4); the number of stations indicating changes in annual means are listed in Table 8. The averages of annual mean values for all stations and for Class I stations are plotted in Figure 8 for the 1977-81 period; both sets of stations show similar trends and levels.

TABLE 8 NITROGEN DIOXIDE - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1977-81)

	Number of Stations			
Period	Decrease	Increase	No change * *	Total
1977-78	8	9	4	21
1978-79*	12	4	7	23
1979-80	15	6	10	31
1980-81	8	6	17	31

* Statistically, the decrease in levels was significant.

** Includes stations indicating differences of less than 1.0 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors.

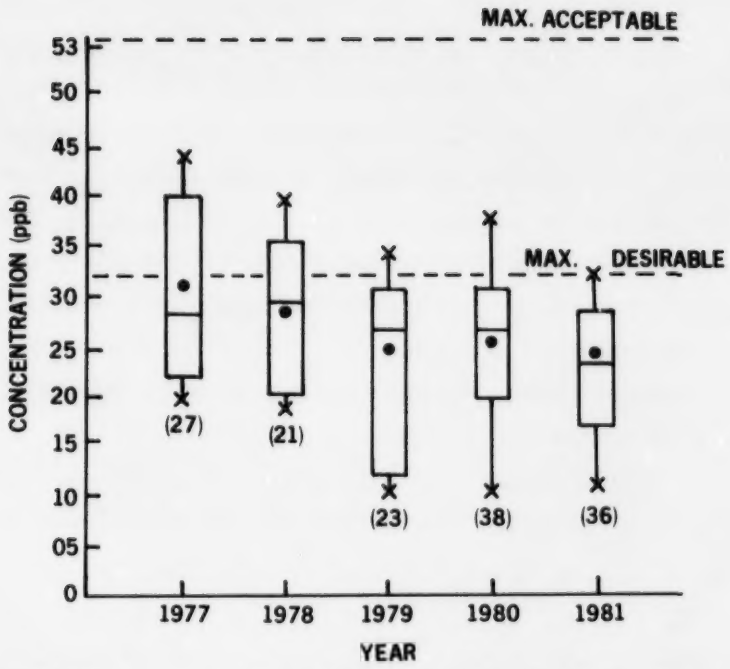

FIGURE 7 NITROGEN DIOXIDE - ANNUAL CONCENTRATION TRENDS IN CANADA (1977-81)

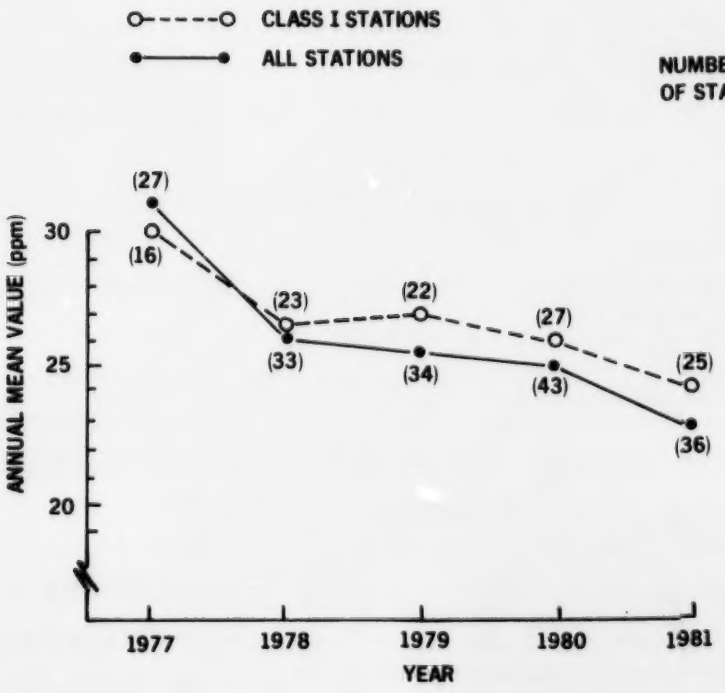

FIGURE 8 TRENDS IN NO_2 ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1977-81)

The average of annual means for nitrogen dioxide did not exceed the maximum desirable level between 1977 and 1981. Furthermore, the percentage of stations reporting levels that meet or exceed the annual air quality objectives each year shows that some improvement in air quality with respect to nitrogen dioxide was achieved. As shown in Table 9A and Figure 9A, the number of stations meeting the maximum desirable level increased from 59% in 1977 to 86% in 1981. No individual station has recorded readings that exceed the maximum acceptable level since 1977. The highest annual mean for nitrogen dioxide in 1981 occurred at a commercial (city centre) site in Edmonton (42 ppb).

TABLE 9 NITROGEN DIOXIDE - PERCENTAGE OF STATIONS IN VARIOUS RANGES WITH RESPECT TO NATIONAL AMBIENT AIR QUALITY OBJECTIVES (1977-81)

	Range (ppb)	1977	1978	1979	1980	1981
A)	**Annual Means**					
	0 - 32*	59	64	76	78	86
	33 - 53**	37	36	24	22	14
	>53	4	---	---	---	---
	No. of stations	27	33	34	37	36
B)	**24-hour Maximum**					
	0 - 110**	84	87	92	90	90
	111 - 160***	16	13	8	10	8
	>160	---	---	---	---	2
	No. of stations	44	47	49	50	49
C)	**1-hour Maximum**					
	0 - 21**	86	87	96	92	86
	211 - 530***	14	13	2	8	14
	>530	---	---	2	---	---
	No. of stations	44	47	49	50	49

* Desirable level
** Acceptable level
*** Tolerable level

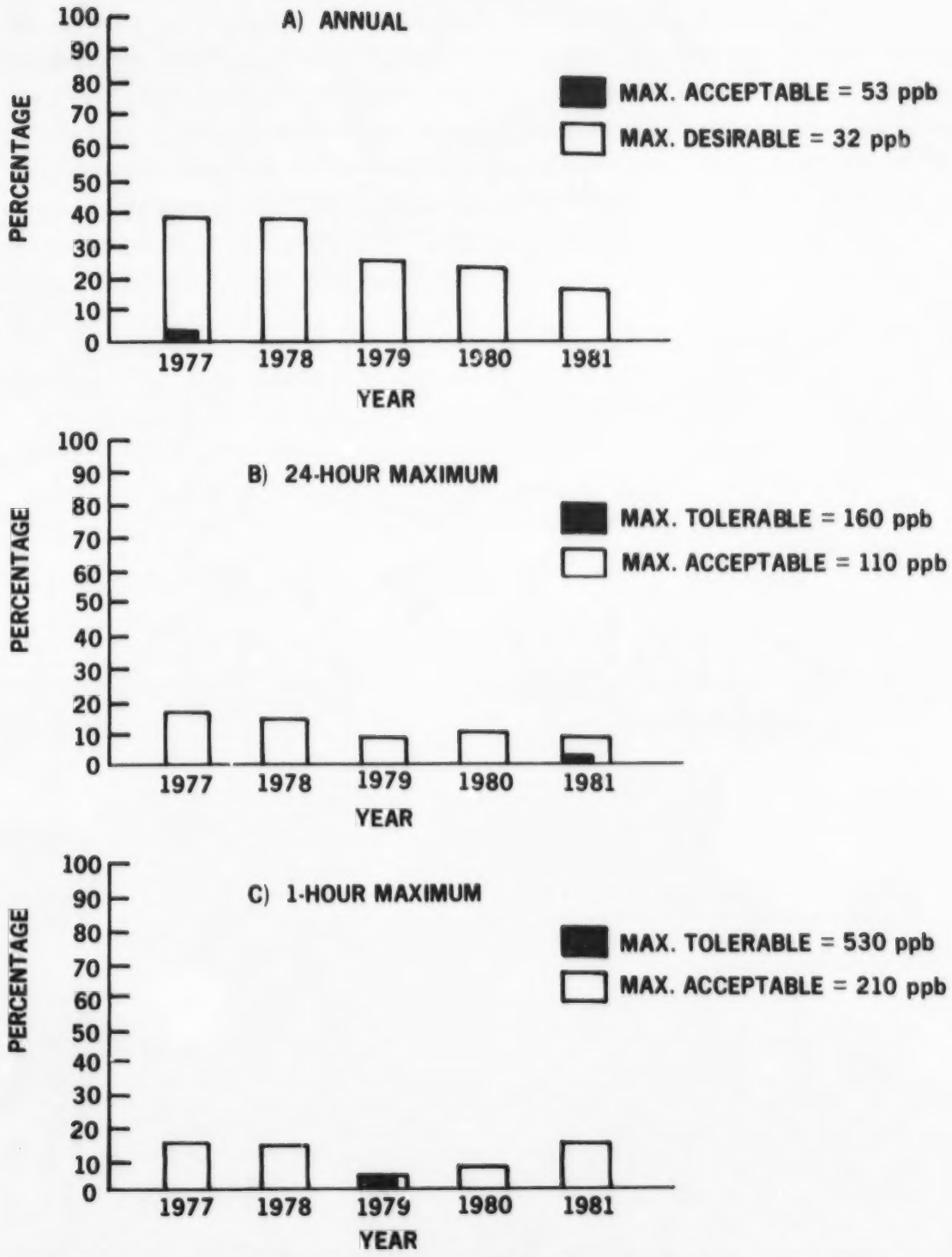

FIGURE 9 NITROGEN DIOXIDE - PERCENTAGE OF STATIONS REPORTING READINGS EXCEEDING NAAQOs (1977-1981)

3.2 Short-Term Concentrations

24-Hour Maximum Levels. Improvements noted in annual mean nitrogen dioxide values were paralleled by a trend to fewer stations reporting readings that exceeded the 24-hour maximum acceptable level of 110 ppb (Figure 9B and Table 9B). In 1977, 84% of the stations reported readings that met the maximum acceptable 24-hour level of 110 ppb, compared with 90% in 1981. Ninety-eight percent of the stations reported readings that met the maximum tolerable 24-hour level of 160 ppb 100% of the time during 1981. The individual stations that reported readings greater than the maximum acceptable 24-hour level during 1981 were located in Toronto, Montreal, Quebec City, Windsor and Kitchener.

1-Hour Maximum Levels. The percentage of stations that reported readings that met the maximum acceptable 1-hour level of 210 ppb was higher in 1979 than in previous years; this level was exceeded at only 8% of the sites (Table 9C and Figure 9C). However, none of the stations have reported readings that exceeded the maximum tolerable 1-hour level (530 ppb) since 1979, and none did so prior to 1979. The maximum tolerable level was exceeded only once, with a maximum concentration of 1 ppm reported.

4 CARBON MONOXIDE

Carbon monoxide is produced by the incomplete combustion of any organic fuel. The primary source of carbon monoxide emissions is the gasoline-powered vehicle. Other important sources are forest fires, vegetative burning, the non-highway use of gasoline, and the petroleum refining process. Ambient air quality objectives for this pollutant are associated with the prevention of chronic health effects in humans.

4.1 Annual Means

The average of CO annual means for the NAPS network decreased from 2.4 ppm in 1974 to 1.7 ppm in 1976, and remained relatively constant during 1976-79 until a decrease was realized in 1980-81 (Figure 10). Increases in the number of readings at stations in more polluted areas in 1978 and 1979 mitigated the downward trend of earlier years.

When statistical analysis was applied to determine whether the change between any two consecutive years was significant, carbon monoxide levels were found to have decreased significantly in 1973-74 and 1974-75 as well as in 1979-80 (Table 3). No trend is indicated for 1980-81. The number of stations indicating changes in annual means for carbon monoxide are summarized in Table 10.

Trends in average carbon monoxide annual means for all stations and Class I stations are shown in Figure 11. As with other pollutants, the trend is similar for these two groups for the most recent years, and it can be concluded that Class I stations by themselves would provide a representative national sample of carbon monoxide levels.

The highest reported annual means in 1981 were 4.3 ppm and 2.7 ppm, recorded at commercial sites in Toronto and Vancouver. Both stations are located downtown near major traffic arteries.

4.2 Short-Term Concentrations

8-Hour Maximum Levels. The percentage of stations exceeding the 8-hour objectives showed a general decline from 1974 to 1978; an increase occurred in 1979, followed by a decrease in 1980 and an increase in 1981 (Figure 12A). The number of stations reporting readings exceeding the maximum acceptable and maximum tolerable levels between 1978 and 1981 account for the fluctuations. The only site reporting concentration values in excess of 17 ppm (maximum tolerable level) was a Toronto station (60416C).

Table 11A summarizes the percentages of stations reporting readings in various ranges with respect to 8-hour NAAQOs from 1974 to 1981.

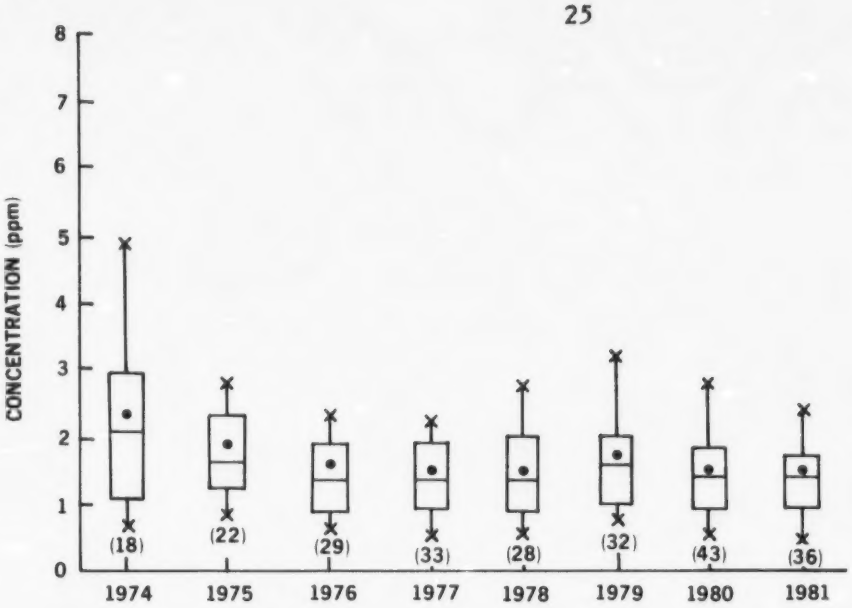

FIGURE 10 CARBON MONOXIDE - ANNUAL CONCENTRATION TRENDS IN CANADA (1974-1981)

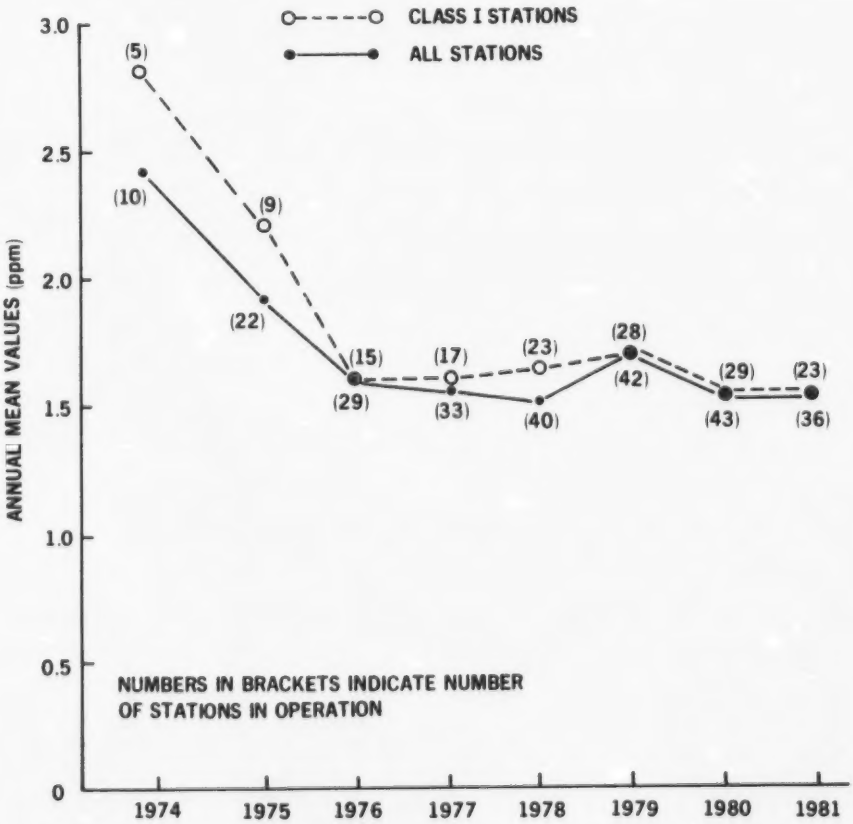

FIGURE 11 TRENDS IN CO ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1974-81)

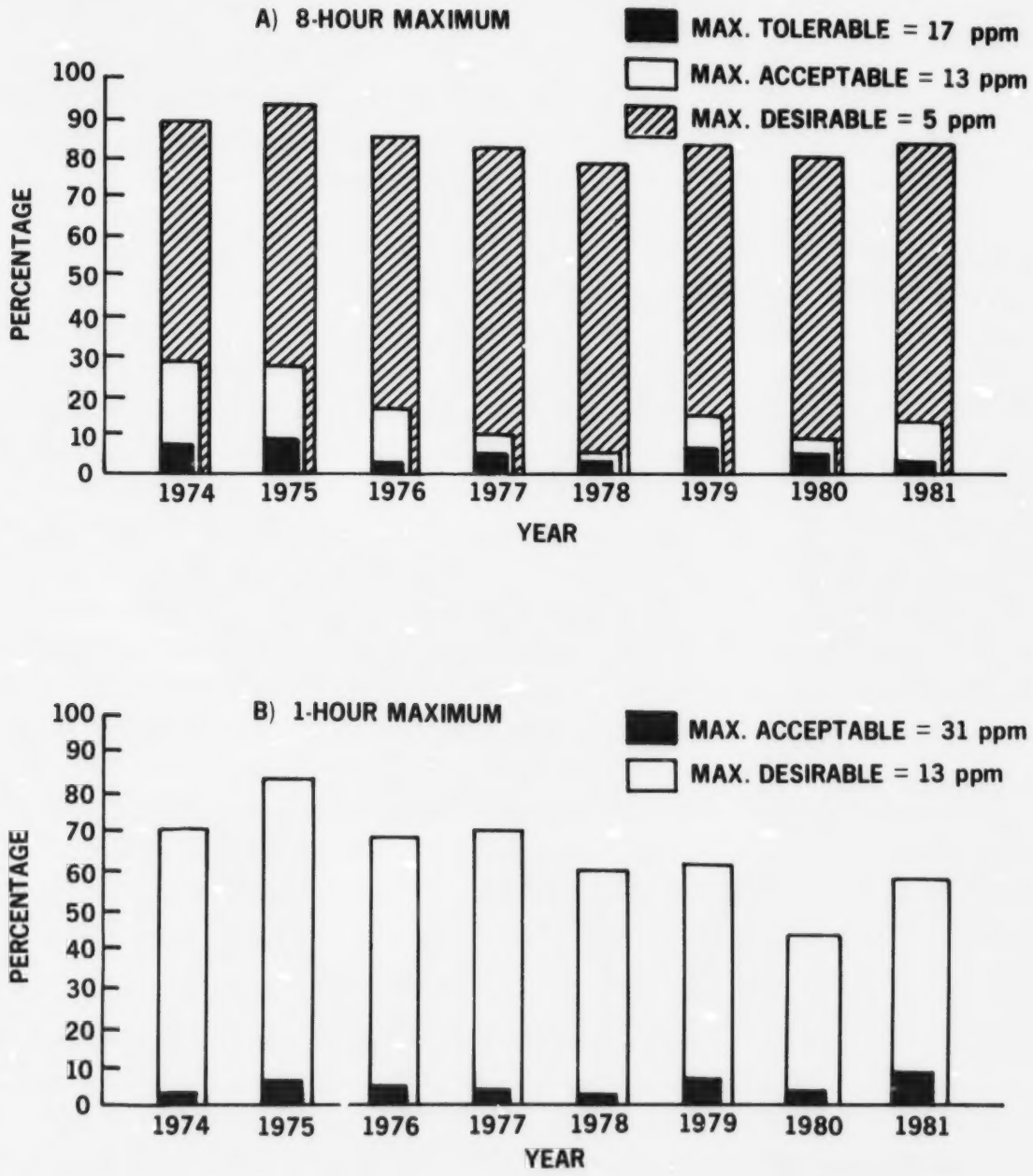

FIGURE 12 CARBON MONOXIDE - PERCENTAGE OF STATIONS REPORTING READINGS EXCEEDING NAAQO'S (1974-1981)

TABLE 10 CARBON MONOXIDE - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1974-81)

Period	Number of Stations			
	Decrease	Increase	No change **	Total
1973-74*	7	1	1	9
1974-75*	9	3	3	15
1975-76	7	9	3	19
1976-77	8	7	9	24
1977-78	8	9	11	28
1978-79	9	10	13	32
1979-80*	17	6	14	37
1980-81	5	8	19	32

* Statistically, there was a significant decrease in carbon monoxide in 1973-74 and 1974-75; and 1979-80.

** Includes stations where differences were less than 0.1 ppm to ensure changes are not due to monitoring instrument inaccuracies or other errors.

1-Hour Maximum Values. The percentages of stations reporting readings exceeding the 1-hour maximum desirable carbon monoxide level of 13 ppm have been decreasing over the years, with a rather sharp decrease occurring in 1980 (Figure 12B). The percentages of stations with readings exceeding the maximum acceptable level varied from 2% to 8%, without any apparent trend since 1974. Readings in excess of the maximum acceptable 1-hour level and the 8-hour maximum tolerable level occurred at only one Toronto site in 1981 (Station 60416C). Other sites where the maximum acceptable 1-hour level was exceeded were Oshawa, Calgary and Vancouver.

Table 11B indicates the percentages of stations in various ranges with respect to the 1-hour NAAQOs from 1974 to 1981.

TABLE 11 CARBON MONOXIDE - PERCENTAGE OF STATIONS WITH READINGS IN VARIOUS RANGES WITH RESPECT TO NATIONAL AMBIENT AIR QUALITY OBJECTIVES (1974-81)

	Range (ppm)	1974	1975	1976	1977	1978	1979	1980	1981
A)	**8-hour Maximum**								
	0 - 5.0*	11	6	14	17	21	18	23	13
	5.1 - 13**	60	67	70	73	71	63	69	73
	13.1 - 17***	22	18	14	6	6	14	4	12
	>17	7	9	2	4	2	6	4	2
	No. of stations	27	33	42	48	52	51	52	52
B)	**1-hour Maximum**								
	0 - 13*	30	18	32	31	42	39	59	46
	13.1 - 31**	67	76	63	65	56	55	38	46
	>31	3	6	5	4	2	6	3	8
	No. of stations	27	33	42	48	52	51	52	52

* Desirable level
** Acceptable level
*** Tolerable level

5 OZONE

Ozone is the principal species of several oxidizing gases known collectively as total oxidants. Atmospheric ozone concentrations increase as a result of photochemical reactions which occur under conditions of strong sunlight and high concentrations of hydrocarbons and nitrogen oxides. These precursors to atmospheric ozone formation are emitted primarily from gasoline-powered motor vehicles, forest fires and diesel engines. Ambient air quality objectives for ozone have been set on the basis of known adverse effects on vegetation, materials and human health.

Ozone monitors were first installed in the NAPS network in 1973 (Figure 1). Data for the 1973-74 period were presented in an earlier report (1). With the subsequent implementation of a common calibration procedure for ozone monitors across the NAPS network, it was found that some of the data could be of questionable value (2). In order to avoid assessments based upon data not suitable for comparison, it was decided to delay the interpretation of ozone data until all questions of methodology were resolved. It is now believed that the ozone measurements made throughout the network after 1978 are reliable and consistent.

5.1 Annual Means

Annual ozone concentrations since 1979 are plotted on Figure 13. The overall average of ozone annual means for the NAPS network in 1981 was 15 ppb. Values for individual stations ranged from 6 ppb in Quebec City (50304C) and Montreal (50109C) to 23 ppb in Cornwall (61201R). Most stations in southern Ontario reported annual means between 10 ppb and 23 ppb. The anticipated seasonal pattern of highest levels during the summer months was generally observed. Trends in average ozone concentrations at all stations and Class I stations are shown in Figure 14. The number of stations indicating changes in annual mean ozone concentrations between 1979 and 1981 is shown in Table 12.

The maximum acceptable annual mean level for ozone is 15 ppb. As shown in Table 13A, about half of the monitoring sites met this objective. The sites exceeding this level were quite evenly distributed across the network, but all southern Ontario sites outside of the Toronto-Hamilton urban area reported readings higher than the maximum acceptable level. The suppression of ozone levels by nitrogen oxide scavenging in urban and industrial areas has been noted previously (9).

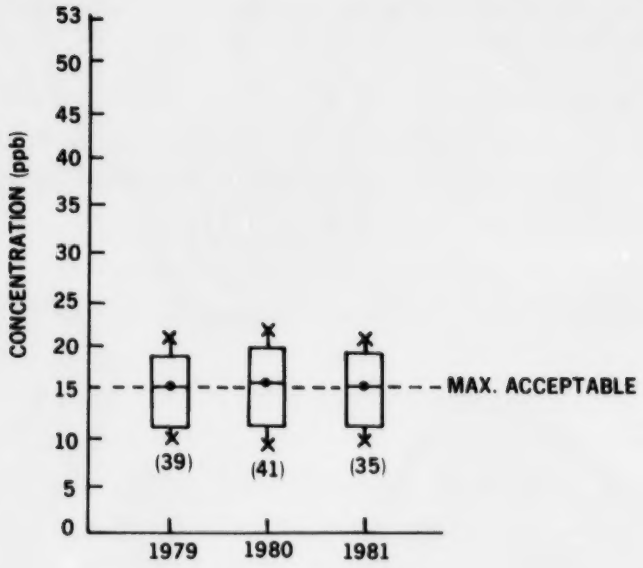

FIGURE 13 OZONE - ANNUAL CONCENTRATION TRENDS IN CANADA (1979-1981)

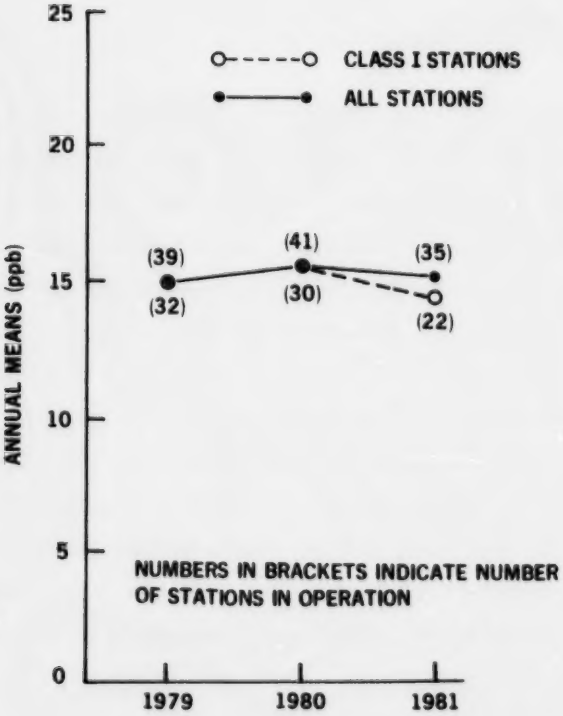

FIGURE 14 TRENDS IN OZONE ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1979-1981)

TABLE 12 OZONE - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1979-1981)

Period	Number of Stations			
	Decrease	Increase	No Change**	Total
1979-80	10	9	15	34
1980-81*	13	4	15	32

* Statistically significant decrease in annual mean.
** Includes stations where differences were less than 0.1 ppb to ensure changes are not due to monitoring instrument inaccuracies or other errors.

TABLE 13 OZONE - PERCENTAGE OF STATIONS WITH READINGS IN VARIOUS RANGES WITH RESPECT TO NATIONAL AMBIENT AIR QUALITY OBJECTIVES (1979-1981)

	Range (ppb)	1979	1980	1981
A)	**Annual Means**			
	0 - 15**	50	46	54
	>15	50	54	46
	Number of stations	38	41	35
B)	**24-hour Maximum**			
	0 - 20*		-	-
	21 - 30**		2	4
	>30	100	98	96
	Number of stations	44	500	50
C)	**1-hour Maximum**			
	0 - 50*	2	4	6
	51 - 80**	16	22	26
	81 - 150***	62	68	58
	>150	20	6	10
	Number of stations	45	50	50

* Maximum desirable
** Maximum acceptable
*** Maximum tolerable

5.2 Short-Term Concentration

24-hour Maximum Levels. Most stations reported 24-hour average values higher than the maximum acceptable level of 30 ppb (Figure 15 and Table 13B). Such values occurred quite regularly during the summer months, particularly at stations in southwestern Ontario.

1-hour Maximum Levels. Maximum desirable, acceptable and tolerable 1-hour mean ozone levels have been established (Table 2). The percentages of stations showing maximum values in the ranges defined by these objectives are summarized in Table 13C. Ten percent of the sites reported values in excess of the maximum tolerable level of 150 ppb. These were, in most instances, single occurrences.

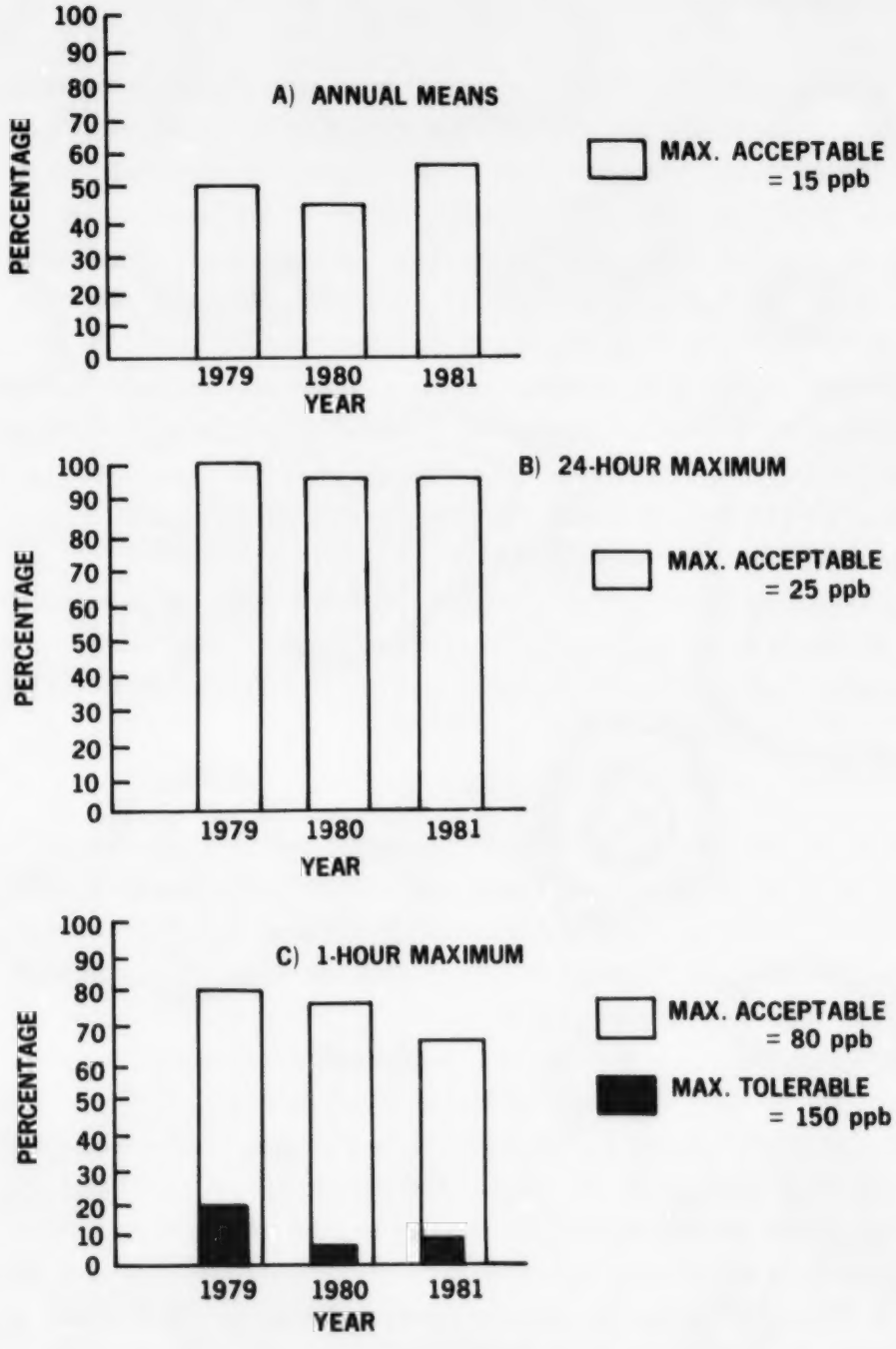

FIGURE 15 OZONE - PERCENTAGE OF STATIONS REPORTING READINGS EXCEEDING NAAQOs (1979-1981)

6 SUSPENDED PARTICULATES

Total suspended particulate (TSP) is a general term applied to a wide variety of solid or liquid particles of a size and configuration such that they tend to remain airborne (aerosol). The portion of fine particulate known as inhalable particulate can be drawn deep into the respiratory tract. Particulate matter is the most commonly perceived form of air pollution, often manifesting itself by impairment of visibility, soiling of materials and irritation of the respiratory tract. Ambient air quality objectives have been established with the goal of minimizing these undesirable effects. A recently initiated monitoring program has been designed to obtain information on particle size distributions and chemical composition of particulate matter in seven Canadian cities in order to increase our knowledge and understanding of this pollutant. The particle size and chemical composition of particulate emissions from the most significant sources of such emissions in Canada are also being determined (10).

Iron ore mining and beneficiation, mining and rock quarrying, sulphate (kraft) pulping, power plants, slash burning, and cement manufacturing are all important sources of suspended particulate matter. Forest fires, wind erosion and fugitive dust emissions contribute to the natural background levels.

6.1 Annual Geometric Means

The overall average of the annual geometric means decreased approximately 25% between 1974 and 1981, and mean values appear to have levelled off in the 50-60 $\mu g/m^3$ range in recent years (Figure 16 and Appendix). The decrease in average levels can be attributed to improved conditions at the more polluted sites. When statistical analysis was applied to determine whether the change in any two consecutive years was significant, TSP levels were found to have decreased significantly in 1974-75, 1976-77 and 1980-81 (Table 14). There were significant increases in 1978-79 and 1979-80. The increases in 1978-79 and 1979-80 appear to have been due to increases at sites where the higher concentrations have occurred in the past. The number of stations indicating changes in annual means from 1974 to 1981 are summarized in Table 14.

Trends in average annual mean values for all stations and Class I stations for 1974-81 are shown in Figure 17. While the general trends indicated by the two sets of stations are similar, the absolute values shown by the Class I stations were significantly higher in 1974 and 1975. For more recent years, the agreement is much improved and it appears that Class I stations alone can provide a representative sample of generally prevailing TSP levels.

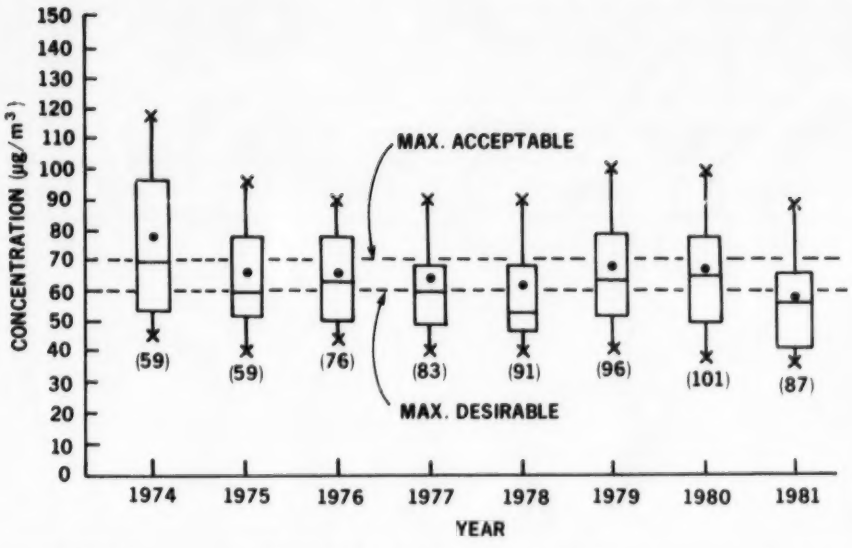

FIGURE 16 SUSPENDED PARTICULATES - ANNUAL CONCENTRATION TRENDS IN CANADA (1974-1981)

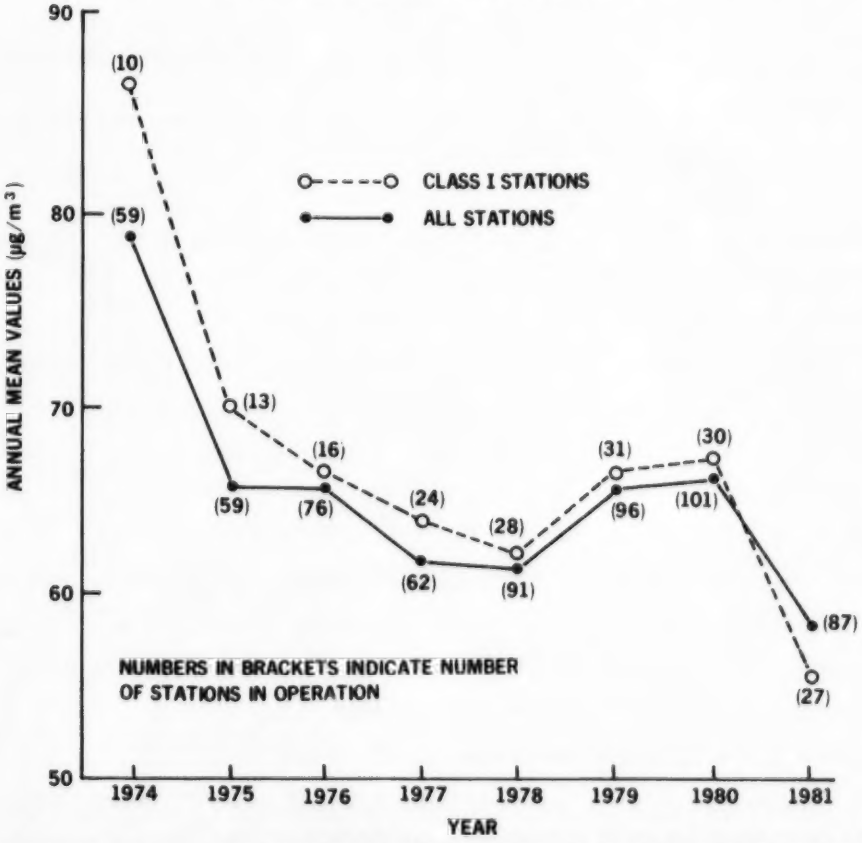

FIGURE 17 TRENDS IN SUSPENDED PARTICULATES ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1974-1981)

TABLE 14 SUSPENDED PARTICULATES - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1974-81)

Period	Number of Stations			
	Decrease	Increase	No change ***	Total
1973-74	16	16	24	56
1974-75*	30	9	12	51
1975-76	14	17	23	54
1976-77*	23	13	31	67
1977-78	26	12	36	74
1978-79**	14	40	31	85
1979-80**	17	34	33	84
1980-81*	42	4	28	74

* Statistically, there was a significant decrease in the annual geometric mean for 1974-75, 1976-77 and 1980-81.

** For 1978-79, 1979-1980 the increase in the annual geometric mean was determined to be statistically significant.

*** Includes stations where differences were less than 4 $\mu g/m^3$ to ensure changes are not due to monitoring instrument inaccuracies or other errors.

As can be seen from Figure 16, the average values of annual means for the past several years have been below the maximum acceptable level but above the maximum desirable level; an exception is 1981, with a mean value below the maximum acceptable. The percentages of stations with annual mean concentrations exceeding the annual objectives are shown graphically in Figure 18A. A trend towards improvement is indicated by the larger percentage of stations with means at the desirable and acceptable levels in 1981. Approximately 20% of the stations measuring TSP concentrations exceeded the maximum acceptable level of 70 $\mu g/m^3$ in 1981, compared with approximately 50% in 1974. Similarly, the percentage of stations with annual means meeting the maximum desirable objective of 60 $\mu g/m^3$ increased from 30% in 1974 to approximately 60% in 1981. The percentage of stations reporting annual means in the various ranges defined by the NAAQOs are summarized in Table 15A.

Stations reporting the highest annual means in 1981 were:

- Calgary stations 90204C and 90218I at 149 $\mu g/m^3$ and 136 $\mu g/m^3$, respectively, with re-entrained dust from unpaved roadways and construction projects a possible predominant source;

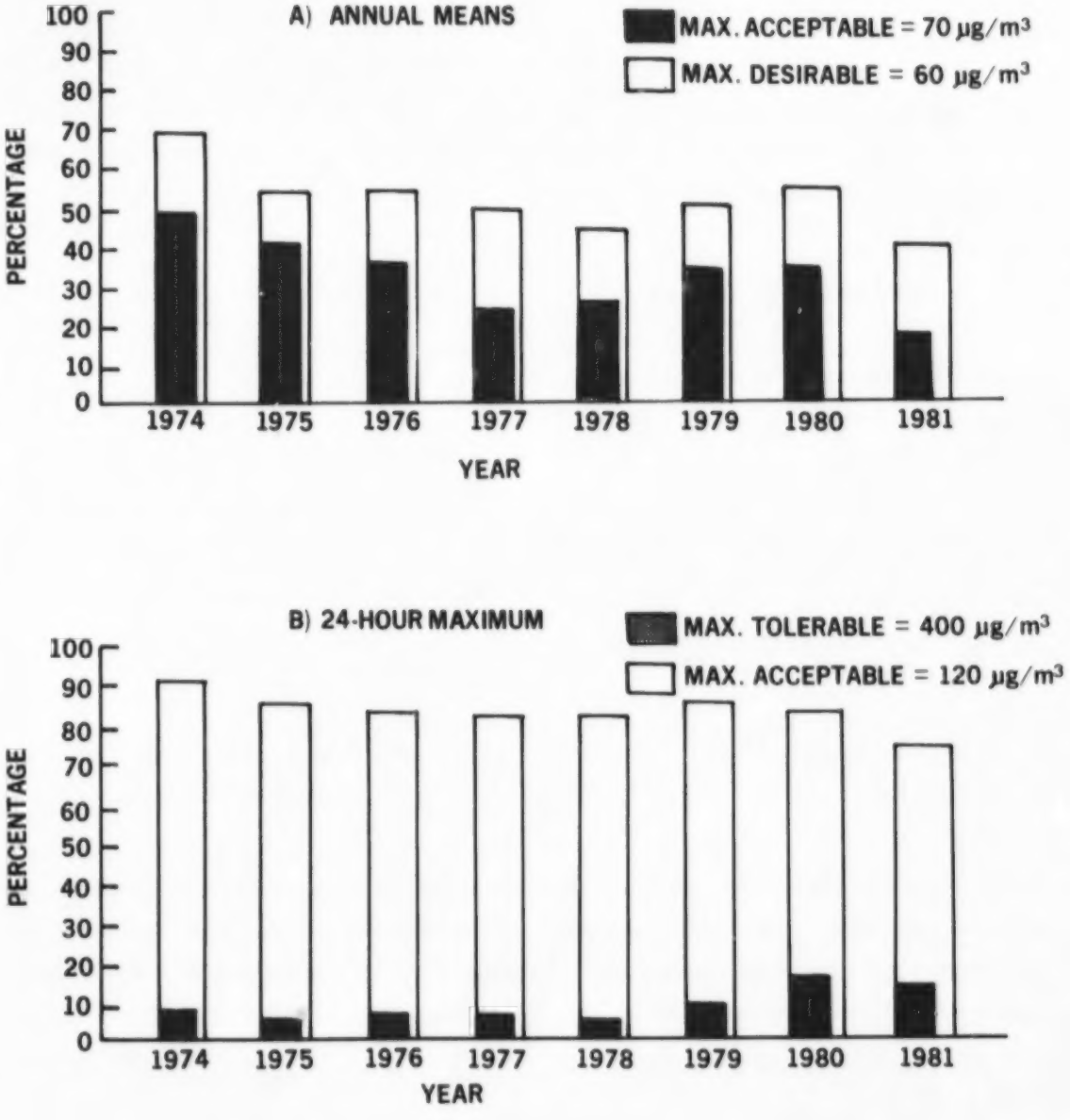

FIGURE 18 SUSPENDED PARTICULATES - PERCENTAGE OF STATIONS REPORTING READINGS EXCEEDING NAAQOs (1974-81)

TABLE 15 SUSPENDED PARTICULATES - PERCENTAGE OF STATIONS WITH READINGS IN VARIOUS RANGES WITH RESPECT TO NATIONAL AMBIENT AIR QUALITY OBJECTIVES (1974-81)

Range ($\mu g/m^3$)	1974	1975	1976	1977	1978	1979	1980	1981
A) Annual Geometric Means								
0 - 60*	32	47	45	50	56	48	44	61
61 - 70**	19	11	18	26	17	18	22	21
> 70	49	42	37	24	27	34	34	18
No. of stations	59	60	76	83	95	95	101	87

* Desirable level
** Acceptable level

B) 24-hour Maximum								
0 - 120*	6	15	17	18	18	11	17	27
121 - 400**	86	80	75	74	77	78	67	61
>400	8	5	8	8	5	10	16	13
No. of stations	72	82	99	106	117	116	116	117

* Acceptable level
** Tolerable level

- Montreal (50109C) at 128 $\mu g/m^3$, with re-entrained dust associated with a traffic density in excess of 100 000 vehicles per day from a nearby expressway the predominant source.

Other cities with stations that regularly reported readings exceeding the maximum acceptable level during the past several years were Montreal, Quebec City, Shawinigan, Hamilton, Windsor, Toronto, Calgary and Edmonton; the probable reasons that the NAAQO levels were exceeded have been discussed in previous reports (1,2).

6.2 Short-Term Concentrations

The percentage of stations reporting readings meeting the maximum acceptable 24-hour level (120 $\mu g/m^3$) between 1974 and 1981 has not changed significantly. Approximately 75% of the stations reported readings that exceeded the maximum acceptable 24-hour level in 1981, compared with approximately 95% in 1974.

About 13 percent of the stations reported 24-hour values higher than the maximum tolerable level (400 $\mu g/m^3$) in 1980 and 1981. This indicates an increase in the number of stations reporting readings exceeding the maximum tolerable level over the years (see Table 15B). However, of these stations, three reported readings that exceeded the maximum tolerable twice and one station four times; the others were single incidents restricted to the month of April. These single incidents occurred in Manitoba, Saskatchewan and Alberta, and after a consultation with the Canada Climate Centre, it was determined that the most likely explanation was that the mild dry winters had increased fugitive dust emissions from summer fallowed fields.

7 LEAD

Lead in the ambient air is recognized as a potential threat to human health. Gasoline-powered motor vehicles account for more than 70% of total airborne lead emissions in Canada. Other sources include the primary production of copper and nickel, and the operations involved in lead mining, milling, smelting and refining (11).

Lead is present in ambient air as a component of suspended particulates and is determined by analyzing the samples collected for suspended particulate determinations.

7.1 Annual Geometric Means

The average of annual mean lead concentrations decreased approximately 50% between 1974 and 1981 (See Appendix and Figure 19). Stations in polluted areas showed consistent improvement as indicated by the decrease in the 90th percentile concentration. Statistical tests to determine the significance of the change between any two consecutive years show that annual lead levels decreased significantly in all years except 1980 to 1981, when no trend was indicated (Table 3). The numbers of stations indicating changes in annual geometric means are listed in Table 16.

Average annual mean lead concentrations measured at stations in the NAPS network are shown in Figure 20. Class I stations show significantly higher levels than do other stations, consistent with Class I locations in downtown urban areas where lead levels can be expected to be higher than average. The data indicate a convergence of the average levels measured by the two sets of stations, but the Class I average continued to be somewhat higher than the overall average from 1978 to 1981. This convergence of values can be expected to continue as more automobiles are converted to the use of unleaded gasoline.

Historically the highest annual mean lead concentrations have occurred in the following cities. Station numbers and the annual means for 1981 are also provided.

Montreal (50109C) 0.62 $\mu g/m^3$
Hamilton (60501C) 0.60 $\mu g/m^3$
Toronto (60403I) 1.1 $\mu g/m^3$, (60415R) 0.62 $\mu g/m^3$
Vancouver (00109C) 0.88 $\mu g/m^3$, (00117R) 0.76 $\mu g/m^3$

Although some of these stations may be near an industrial source such as a smelter or a metal remelting operation, one common feature is their proximity to high traffic density or, more specifically, to the major source of lead emissions - the gasoline powered motor vehicle.

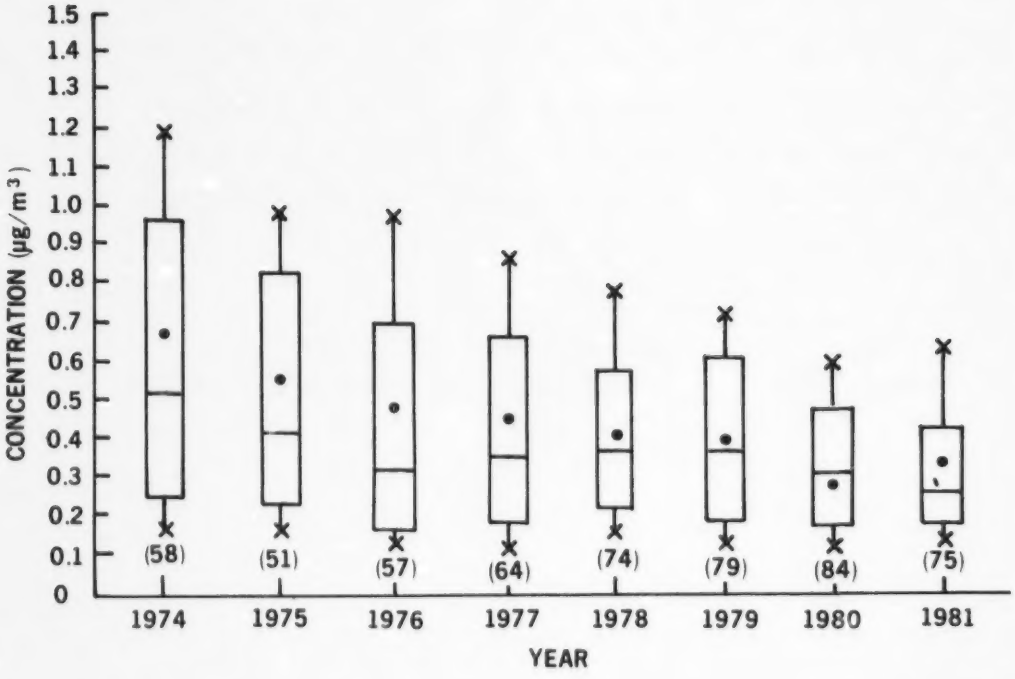

FIGURE 19 LEAD - ANNUAL CONCENTRATION TRENDS IN CANADA (1974-1981)

TABLE 16 LEAD - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1974-81)

	Number of Stations			
Period	Decrease	Increase	No change **	Total
1973-74*	28	8	19	55
1974-75*	23	3	23	49
1975-76*	19	3	20	42
1976-77*	18	3	26	47
1977-78*	30	7	18	55
1978-79*	28	6	22	56
1979-80*	30	6	33	69
1980-81	19	10	29	59

* The Wilcoxon test indicated that lead levels decreased significantly between 1974 and 1981.

** Includes stations where differences were less than 0.04 $\mu g/m^3$ to ensure changes are not due to monitoring instrument inaccuracies or other errors.

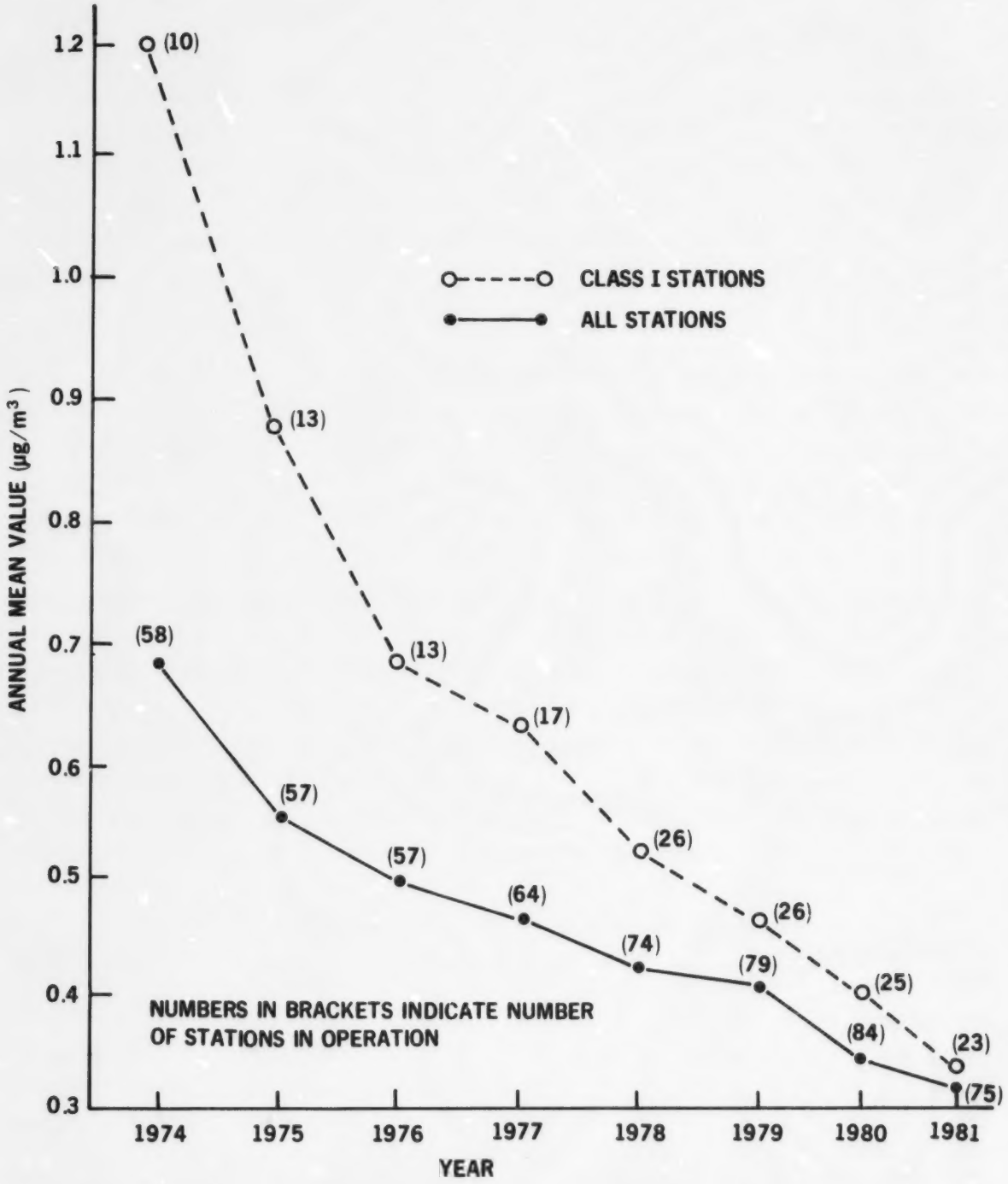

FIGURE 20 TRENDS IN LEAD ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1974-1981)

7.2 Short-Term Concentrations

No ambient air quality objectives have been established for lead (7). However, a comparison of the national averages of the 24-hour maxima for recent years gives some indication of the decreasing trend in maximum lead levels at the NAPS monitoring sites:

Year	$\mu g/m^3$
1974	3.0
1975	2.5
1976	2.0
1977	2.1
1978	1.8
1979	1.6
1980	1.4
1981	1.1

This downward trend in maximum values parallels the pattern in annual mean values shown in Figure 19.

8 SOILING INDEX

The soiling index indicates the soiling or darkening potential of fine particulate contaminants in the atmosphere, measured in coefficient of haze units. No NAAQOs have been set for this parameter. Likely sources of COH are fuel combustion, industrial processes, vehicle exhaust, forest fires, vegetation burning and fugitive dust emissions.

As shown in Figure 21 (and Appendix), the average annual index decreased substantially between 1974 and 1981. The decrease from 0.38 units in 1974 to the average value of 0.30 units in 1980 and 1981 is approximately 20%. Reduced levels at the stations in traditionally more polluted areas accounted for most of the decrease in the average values.

Despite the apparent long-term improvement in average index levels, statistical analysis of the significance of changes between consecutive years has shown that no significant changes occurred until recently (Table 17). The distribution of annual means for 1980 in Figure 21 shows less spread from the 90^{th} to the 10^{th} percentile than ever before, indicating a statistically significant decrease. The trend towards an increase in 1981 can similarly be observed in the greater spread of values from the 90^{th} to 10^{th} percentile, and the slightly higher the annual mean. These trends are supported by the data presented in Table 17.

Trends in average annual mean soiling index values for Class I stations and for all NAPS network stations are shown in Figure 22. Increasing agreement has occurred between values from Class I stations and values from all stations in recent years. The Class I stations do, however, tend to show higher index values than do all stations; this is consistent with their central urban locations.

The previously reported (2) occurrence of higher than average soiling index values in stations in the cities of Montreal, Toronto, Hamilton, Windsor and Vancouver continued during 1980 and 1981. The North Park (60505R) station in Hamilton reported the highest annual mean in 1981 (0.72 COH units). Both the steel mill complex on the southwest shore of Hamilton harbour and the heavy traffic on the Queen Elizabeth Way can be expected to contribute to high soiling index levels at this site.

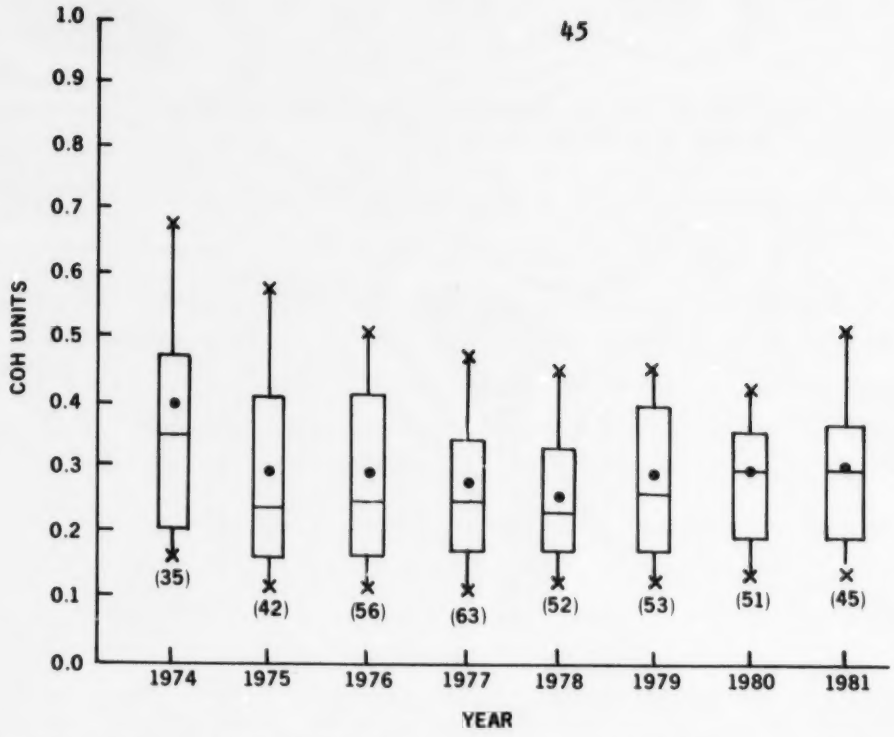

FIGURE 21 SOILING INDEX - ANNUAL TRENDS IN CANADA (1974-1981)

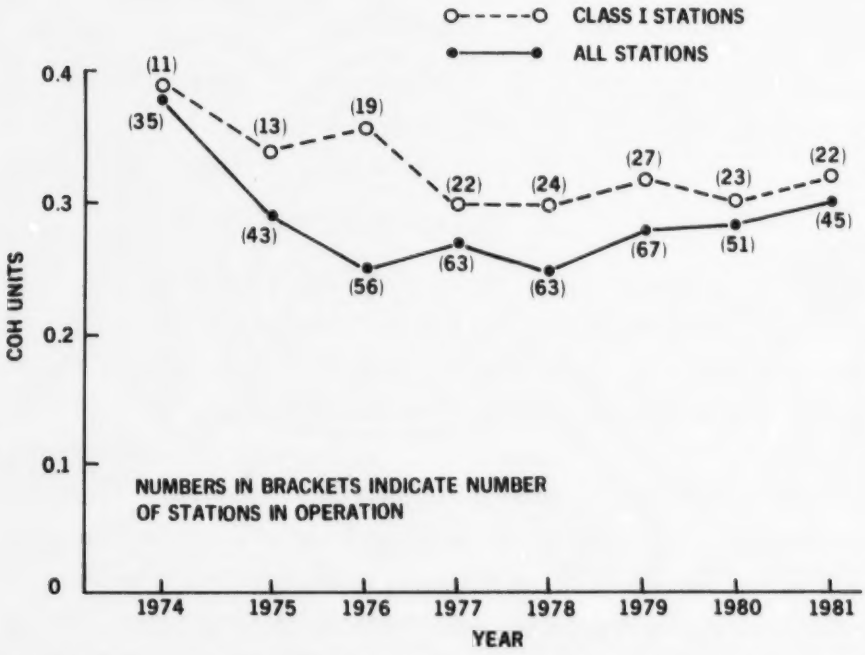

FIGURE 22 TRENDS IN SOILING INDEX ANNUAL MEAN VALUES FOR ALL STATIONS AND CLASS I STATIONS (1974-1981)

TABLE 17 SOILING INDEX - NUMBER OF STATIONS INDICATING CHANGES IN ANNUAL MEAN (1974-81)

Period	Number of Stations			
	Decrease	Increase	No change *	Total
1973-74	13	13	7	33
1974-75	12	10	5	27
1975-76	16	16	7	39
1976-77	16	12	19	47
1977-78	21	13	18	52
1978-79	18	20	15	53
1979-80**	21	12	9	42
1980-81***	4	16	17	37

* Includes stations indicating differences of less than 0.01 COH units to ensure changes are not due to monitoring instrument inaccuracies or other errors.

** Denotes a significant decrease using a Wilcoxon test.

*** Denotes a significant increase using a Wilcoxon test.

9 ANNUAL AIR QUALITY INDEX

9.1 Basis of the Air Quality Index

An annual air quality index reduces complex and voluminous air monitoring data for numerous air contaminants to a single number which can be used to give some indication of overall air quality. The National Ambient Air Quality Objectives are used to provide a common scale with which to quantify the effects of different pollutants on the quality of the air. Conceptual details and guidelines on the use of the index have been published elsewhere (6); only the main assumptions will be summarized here:

a) The index is based on valid air quality data from Class I monitoring stations.
b) The index is based on the average of the three different pollutants that have the most significant effect on air quality.
c) At the defined levels, the effects of all pollutants are equally significant with respect to the quality of the air.
d) The index is based on the measured levels of air quality that are not exceeded by more than 2% of readings taken as recommended by the World Health Organization.
e) If more than one index can be computed for a given pollutant, the largest index is used to represent that pollutant.

Because of these various assumptions, the index can be described as "severe", in that it is based upon 98th percentile concentrations and the largest index computed, rather than on average conditions.

9.2 Air Quality Indexes (1977-81)

Calculated annual air quality index values for all Class I stations in operation during 1977-81 are summarized in Table 18. A qualitative descriptor (Good, 0-25; Fair, 30-50; and Poor, 50+) has been assigned to each station based on 1980-81 data. As individual stations do not show large year-to-year variations, it is probably premature to attempt to quantitatively assess such trends.

The majority of the sites may be categorized as "Fair". Three sites showed an index of less than 25 (Good) for at least one of the past two years (1980-81). Three sites have shown "Poor" indexes of greater than 50 in at least one of these years. These three stations are all commercial sites under the influence of heavy vehicular traffic.

TABLE 18 INDEX OF AIR QUALITY FOR CLASS I STATIONS (1977-81)

City	Number	Station	1977	1978	1979	1980	1981	Category
Halifax	30116C	Barrington & Duke	22	22	26	26	27	
Saint John	40202C	Post Office	--	--	--	37	34	
Montreal	50115C	Peel & Maisonneuve	45	50	46	51	50	P
	50116R	3161 Joseph, Verdun	--	--	39	35	36	
	50102R	Jardin Botanique	39	37	34	35	26	
	50109C	Duncan & Decarie	43	49	51	50	47	
	50112C	Boul. Laurentides	--	35	30	26	29	
	50110C	Parc Pilon, Mtl-Nord	--	--	31	34	36	
Hull	50203R	Gamelin & Joffre	--	20	28	19	20	G
Quebec City	50304C	155 Dorchester Sud	58	47	47	44	37	
Ottawa	60101C	88 Slater Street	42	39	38	35	24	
Windsor	60204C	471 University	46	46	33	43	42	
Toronto	60401C	67 College Street	40	43	44	42	41	
	60412R	Bathurst & Wilson	44	42	45	38	39	
	60410R	Lawrence & Kennedy	37	40	40	35	41	
	60415R	Queensway W. Hurontario	--	40	40	38	43	
	60402R	Don Mills,Science Centre	--	--	31	31	33	
	60413R	Elmcrest Road	36	41	34	34	38	
Hamilton	60501C	Barton & Sanford	51	51	48	40	43	
London	60901C	King & Rectory	44	42	44	42	41	
St. Catharines	61301C	North St. & Geneva St.	46	42	38	33	40	
Kitchener	61501C	Edna & Frederick	41	47	41	41	43	
Winnipeg	70119C	65 Ellen Street	--	39	40	53	39	P
	70118R	Jefferson & Scotia	34	28	44	41	35	
Regina	80109C	1620 Albert Street	--	--	40	41	52	P
Edmonton	90130C	10255-104th Street	48	48	53	48	43	
	90122R	127 St. & 133 Avenue	39	41	45	39	39	
Calgary	90227C	1611-4th Street S.W.	48	49	56	32	29	
	90222R	39 St. & 29 Ave. N.W.	36	35	37	46	36	
Vancouver	00112C	Robson & Hornby	36	32	37	31	42	
	00106R	2294 West 10th Avenue	36	34	40	27	30	
	00108I	250 West 70th Avenue	40	36	42	33	34	
	00110R	E. Hastings & Kensington	33	36	36	26	23	G
	00111I	Rocky Pt. Park	--	26	32	40	43	
Victoria	00302C	1106 Cook Street	29	23	23	18	22	G

Index	Category
0 - 25	Good
26 - 50	Fair
51 - 100	Poor
100+	Very Poor

Note: Because most of the stations fall into the "Fair" category only poor and good stations are designated.

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APPENDIX

SUMMARY DATA - NATIONAL URBAN AIR QUALITY TRENDS 1970-1981

SUMMARY DATA - - URBAN AIR QUALITY IN CANADA, 1970-1981

Pollutant	Year	Number of Sites	Average of Annual Mean	Percentage of Sites with Annual Mean Lower than Given Values				
				90%	75%	50%	25%	10%
SO_2 (ppb)	1972	34	21	37	29	16	10	<10
	1973	39	16	32	19	<10	<10	<10
	1974	27	16	26	22	12	<10	<10
	1975	36	15	23	19	11	<10	<10
	1976	48	14	24	20	11	<10	<10
	1977	59	14	23	15	<10	<10	<10
	1978	71	13	20	13	<10	<10	<10
	1979	69	12	18	13	<10	<10	<10
	1980	65	12	18	13	<10	<10	<10
	1981	51	11	14	11	<10	<10	<10
NO_2 (ppb)	1977	27	31	44	39	27	21	19
	1978	33	29	40	35	29	20	18
	1979	34	26	34	31	27	19	12
	1980	38	25	37	31	23	19	11
	1981	36	23	32	29	22	16	11
CO (ppm)	1973	10	27	43	33	25	21	11
	1974	18	24	50	30	22	12	07
	1975	22	19	28	24	17	13	08
	1976	29	16	24	19	14	09	07
	1977	33	16	23	19	14	09	05
	1978	40	15	28	20	13	08	05
	1979	42	17	32	20	15	10	08
	1980	43	15	28	18	14	09	06
	1981	36	15	23	16	14	09	05
Ozone (ppb)	1979	39	15	20	18	15	12	10
	1980	41	16	21	20	16	12	09
	1981	35	15	20	18	15	12	10
SP ($\mu g/m^3$)	1970	37	81.9	118.0	106.0	77.0	53.0	43.0
	1971	51	78.6	121.0	104.0	73.0	56.0	41.0
	1972	59	70.4	99.0	90.0	62.0	50.0	38.0
	1973	71	74.8	121.0	97.0	69.0	57.0	47.0
	1974	59	78.6	121.0	96.0	70.0	53.0	43.0
	1975	59	65.9	98.0	77.0	61.0	51.0	39.0
	1976	76	65.7	91.0	78.0	64.0	50.0	43.0
	1977	83	61.9	93.0	69.0	61.0	48.0	39.0
	1978	91	61.4	92.0	68.0	53.0	44.0	36.0
	1979	96	66.0	99.0	78.0	60.0	50.0	38.0
	1980	101	67.0	99.0	77.0	64.0	50.0	40.0
	1981	87	58.6	80.0	66.0	56.0	42.0	37.0
($\mu g/m^3$)	1971	38	0.67	1.18	0.89	0.61	0.39	0.31
	1972	56	0.70	1.22	0.94	0.65	0.31	0.23
	1973	71	0.74	1.40	0.98	0.54	0.31	0.18
	1974	58	0.68	1.22	0.97	0.53	0.26	0.15
	1975	57	0.55	1.00	0.83	0.41	0.23	0.15
	1976	57	0.49	1.00	0.70	0.32	0.17	0.11
	1977	64	0.46	0.89	0.67	0.36	0.19	0.10
	1978	74	0.42	0.75	0.57	0.36	0.23	0.14
	1979	79	0.39	0.72	0.55	0.36	0.21	0.12
	1980	84	0.34	0.60	0.47	0.30	0.17	0.10
	1981	75	0.32	0.62	0.41	0.24	0.17	0.11
Soiling Index (COH)	1970	18	0.51	0.94	0.83	0.39	0.26	0.13
	1971	30	0.43	0.71	0.60	0.34	0.24	0.18
	1972	34	0.42	0.85	0.63	0.34	0.18	0.13
	1973	41	0.40	0.74	0.45	0.35	0.19	0.12
	1974	35	0.38	0.67	0.46	0.34	0.20	0.14
	1975	42	0.28	0.56	0.40	0.23	0.16	0.11
	1976	56	0.28	0.49	0.40	0.24	0.16	0.10
	1977	63	0.27	0.47	0.33	0.24	0.17	0.10
	1978	63	0.25	0.44	0.32	0.22	0.17	0.11
	1979	67	0.28	0.45	0.39	0.26	0.18	0.15
	1980	51	0.28	0.43	0.34	0.28	0.18	0.13
	1981	45	0.30	0.54	0.35	0.29	0.18	0.12